Proceedings of the 2015 Australasian Road Safety Conference

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The Australasian Road Safety Conference, is a merger of two annual conferences run in Australia, namely the Road Safety Research, Policing and Education Conference and the Australasian College of Road Safety Conference. Both were popular annual events for both researchers and practitioners in the fields of road safety for a number of decades. However, it was deemed by Australia's road safety regulators, researchers, and experts that the two conferences should be merged into one large conference. This is the first year this merged conference is being run.

These proceedings describe research on road safety, the implementation of road safety programs and related enforcement activities, primarily in Australia but also internationally. Papers presented have come from University based research institutions, professional consultants, government agencies, community groups and interested individuals.

The Conference Organising Committee allowed five types of submissions for the Conference: keynote papers, full papers, extended abstracts, posters and conference symposia papers. Each abstract submitted was double blind peer-reviewed by two peer-reviewers. For those Abstracts accepted to the conference, the Authors had a choice of having their submissions peer-reviewed or submitted to the non-peer-review stream.

For those submissions where peer-review was requested a Conference Editor with senior peer status in the respective field of road safety was assigned as the submission handler. The Conference Editor then selected the Peer Reviewers and thereafter handled the peer-review process, submitting their decision of 'accept', 'revise' or 'reject' to the Proceedings Editors. Thus each paper was essentially peer-reviewed by three experts in the paper's classification field. Where necessary, authors amended papers to the satisfaction of the Peer Reviewers, the respective Conference Editor and Proceedings Editors. For those submissions that were peer-reviewed they are identified in the header as 'Peer review stream'.

Non-peer reviewed papers, extended abstracts, posters and conference symposia papers were reviewed only by select Conference Editors for applicable content and format. For those submissions that were not peer-reviewed they are identified in the header as 'Non-peer review stream'.

The Proceedings Editors would like to thank in particular the Conference Editors who handled each paper and the Peer Reviewers of the papers and are most grateful to all these people for giving up their valuable time.

The Proceedings Editors would also like to warmly thank all the keynote speakers and presenters, the respective Conference Organising and Scientific Committees, the conference sponsors and session chairs. The valuable input and enthusiasm of all these people and groups for road safety will ensure the 2015 Australasian Road Safety Conference meet the needs of the diverse range of participants and contribute to the overall success of each event. More importantly it is hoped that these proceedings will contribute to the knowledge bank that will help reduce road trauma both in Australia and internationally.

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Grzebieta RH, Armstrong K, Lewis I., Tunks L., Howe C. and Murray C.

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Program Day 1: Wednesday 14 October 2015

8.00am	**Registration Opens** Registration Desk, Ground Floor
9.30am	**Arrival Tea and Coffee** Conference Exhibition Foyer E & F, Upper Level

Concurrent Session 1

10.00am – 12noon

Arena 1B	Room 4	Room 5	Room 6	Room 7	Room 8	Room 9
Symposium: Factors Influencing Young Driver Risk Sponsored By: Motor Accident Insurance Commission	**Road Safety Infrastructure**	**Workshop: Road Safety Education in Schools**	**Workshop: Policing and Enforcement - Collaborative Action for Change**	**Driver Distraction**	**Vehicle Safety and Design**	**Road Safety Management and Strategy**
Curbing the Attention-Deficit: Influences of Task Demand During On-Road Driving Nastassia Randell, University of Waikato	**Local Road Mountable Roundabouts: Are there safety benefits?** Nimmi Candappa, Monash University Accident Research Centre	**9am - 12noon Workshop: Road Safety Education in Schools** This program will review evidence-based research surrounding road safety education including selecting appropriate road safety programs and reviewing the effectiveness of existing programs. An important component of this workshop will be road safety education in the Australian Curriculum and a participant workshop session centred on road safety curriculum alignment using Queensland curriculum support materials (C2C). Curriculum into the Classroom (C2C) resources are provided to support schools to implement the Australian Curriculum. C2C resources assist with planning, teaching, learning and assessment of the Australian Curriculum. A presenter from C2C will be providing a workshop session with a teaching focus, demonstrating how road safety education can be incorporated into the classroom.	**Welcome and Introductions** Deputy Commissioner Brett Pointing, Queensland Police Service	**Exploring the role of healthy distraction on driver performance** Kristen Pammer, The Australian National University	**Review of injury mitigation strategies and methods of assessment for passenger vehicle rollover crashes in Australia** Garrett Mattos, University of NSW	**Road Safety Audits in Australia 20 Years After Inception: Examination of practical issues and limitations** Peter Harris, Road Safety Audits Pty Ltd
Impulsivity and Aggression in Young Drivers Assessed in Short Driving Simulator Scenarios Trevor Hine, Griffith University	**The Hurdles of Introducing Innovative Road Safety Infrastructure Solutions: A case study on raised platforms** Blair Turner, ARRB Group Ltd		**Road Policing: The experience in Queensland** Assistant Commissioner Mike Keating	**Maximising Positive Driver Behaviour Change and Minimising Driver Distraction in the Deployment of Cooperative Intelligent Transport Systems** Vanessa Vecovski, Transport for NSW	**Effect of vehicle roof shape on rollover safety** Keith Simmons, University of NSW	**Safe System Auditing: Principles to practice** Ken Beer, Safe System Solutions Pty Ltd
Young Driver Perceived Risk and Risky Driving: Applied theoretical approach to the Fatal Five Emma Harbeck, Griffith University	**When, Where and Why Road Accidents are Likely to Happen on the Kings Highway, NSW** Sahar Alian, University of New England		**ANZPAA Road Policing Forum - Collaborative Action for Change** Assistant Commissioner John Hartley, NSW Police	**Digital Billboards "Down Under". Are they distracting to drivers and can industry and regulators work together for a safe outcome?** Carolyn Samsa, Samsa Consulting	**Predicting occupant risk indicators for frontal impacts with redirective crash cushions** Andrew Burbridge, Queensland Government	**Application of Program Logic for Policy Development and Evaluation** Ben Barnes, NSW Centre for Road Safety
Perceived Risk, Speed and Countermeasures Nicola Starkey, University of Waikato	**Who does what, where and why? Optimising allocation of functions in rail level crossing systems** Christine Mulvihill, Monash University Accident Research Centre		**Future of Policing: The European experience** General Secretary Ruth Purdie, TISPOL		**The impact of airbags, electronic stability control and autonomous emergency braking on Australian light vehicle fatalities: methodology and findings** Jack McAuley, Department of Infrastructure and Regional Development	**Building New Partnerships to Improve Road Safety Risk** Robyn Gardener, Accident Compensation Corporation
Learn, Drive, Survive: Drives for Learners in the Moreton Bay Region' - A practical tool for Supervisors and Learner Drivers Kerrie Doherty, Moreton Bay Regional Council					**Establishing a testing capability for the assessment of Autonomous Emergency Braking (AEB) and Forward Collision Warning (FCW) in Australia** Andrew Van den Berg, The University of Adelaide	**Australian National Risk Assessment Model** Michael Gilles, Queensland Department of Transport and Main Raods

12noon	**Lunch** **Sponsored by: Aurizon** Conference Exhibition Foyer E & F, Upper Level

Concurrent Session 2

1.00pm – 2.30pm

Arena 1B	Room 4	Room 5	Room 6	Room 7	Room 8	Room 9
Attitudes Influencing Young Driver Risk	**Symposium: Road Safety Barriers for Cars and Motorcycles Sponsored By: CSP Pacific**	**Road Safety Education**	**Workshop: Policing and Enforcement - Collaborative Action for Change**	**Cycling Safety**	**Work Related Road Safety**	**Vehicle and Signage Technology**
New Zealand Youth Traffic Offences and Traffic Offending: Phase 1 Data Gathering Gerald Waters, Researching Impaired Driving in New Zealand	**Road Safety Barriers: International experiences and new directions for Australia** Leith Morris, Humes	**The NZ Transport Agency, Teachers and Educators Design Evidence Based Road Safety Education in NZ Schools** Paul Graham, New Zealand Transport Agency	**"Front-line Mobility - The Queensland experience"** Acting Inspector Gavin Raison, Queensland Police Service	**Factors involved in cyclist fatality crashes: a systematic Literature Review** Marilyn Johnson, Monash University	**The long drive home: control beliefs and commuting intentions of mine workers** Candice Potter, CARRS-Q, Queensland University of Technology	**A new approach to evaluating new vehicle safety technologies using meta-analysis** Brian Fildes, Monash University Accident Research Centre

1.00pm – 2.30pm	**Sleepy Driving and Drink Driving: Attitudes, behaviours, and perceived legitimacy of enforcement of younger and older drivers** Christopher Watling, CARRS-Q, Queensland University of Technology	**Improving Road Safety Barrier Effectiveness: Issues and opportunities** Rod Troutbeck, Rod Troutbeck and Associates	**The Social Impacts of a Road Safety Education Program** David Murray, Road Safety Education Ltd	**Technology in Speed Camera Enforcement Now and into the Future** Dennis Walsh, Queensland Department of Transport and Main Raods Inspector Allan Hales, Queensland Police Service	**A Typology of Laws in Australia Concerning the Safety of Bicycle Users** Simon Elder, University of NSW	**Predicting safe driving behaviour of professional bus drivers: Validation of psychometric tests using real driving performance** Robert Newman, Schuhfried Australia	**Low severity rear impact simulations with average male and female dummy models in Euro NCAP test configuration** Astrid Linder, Swedish National Road and Transport Research Institute
	Difficulties in engaging novice disqualified drivers in a longitudinal study into their behaviours and attitudes Chelsey Key, Government of South Australia	**Motorcyclist Collisions with Roadside Barrier Motorcyclist Protection Systems** Raphael Grzebieta, University of NSW	**Crash Scene Investigation: The Science of Motion - Applying the Year 10 Science Curriculum to Reduce Crash Outcomes** John Illingworth, South Australia Police	**Speed Dating Session: "If money was no option, what would a road policing enforcement model look like?"** Speakers to include: Dr Barry Watson, CEO, Global Road Safety Partnership Assistant Commissioner John Hartley, NSW Police Peter Kolesnik, Queensland Department of Transport and Main Roads	**Using Smartphones for Cycling Safety: A survey of riders preferences and interests in new technologies** Sébastien Demmel, CARRS-Q, Queensland University of Technology	**To Serve and be Protected: Combining road safety with work health and safety** Michael Timms, NSW Police	**Effectiveness of portable speed warning signs** Anthony Burke, Brisbane City Council
	"Holy crap that was close": A qualitative exploration of driving stress and driving discourtesy Bridie Scott-Parker, University of the Sunshine Coast		**An Intergrated Response to the Risks of Violence Against Bus Drivers: When on board assults affect safety on our roads** Shane Stockill, Workplace Health and Safety Queensland		**Coverage of cyclist crashes in Australian newspapers, 2010-2013** Soufiane Boufous, University of NSW	**The prevalence of affective and anxious states within a population of Australian professional drivers** Taryn Chalmers, University of Technology Sydney	**Reducing the response times of emergency vehicles in Queensland** Chris Fullelove, Transmax Pty Ltd
2.30pm	**Afternoon Tea** Conference Exhibition Foyer E & F, Upper Level						

Concurrent Session 3

	Arena 1B	Room 4	Room 5	Room 6	Room 7	Room 8	Room 9
	Graduated Driver Licencing	**Symposium: The National Road Safety Partnership Program Providing a Pathway for any Business/organisation to Create a Positive Road Safety Culture**	**Road Safety Education**	**Workshop: Policing and Enforcement - Collaborative Action for Change**	**International Perspectives in Road Safety**	**Symposium: Safety of Workers at Roadwork Sites**	**Symposium: Who is Responsible for Road Safety?**
3.00pm – 4.30pm	**Development of the Australian Graduated Licensing Scheme Policy Framework: A demonstration of jurisdictions taking action together to reduce road trauma** Ralston Fernandes, Transport for NSW	**The Total Cost of Fleet Risk** Mervyn Rea, Viva Energy	**Study of Current Factors Affecting Road safety for 16-18 Year Old Novice Drivers in the Wingecarribee Shire** Sue Tyler, Highlands Drive Safe	**Joint Heavy Vehicle Enforcement Partnership - NSW Roads & Maritime Service and NSW Police** Inspector Phil Brooks, NSW Police	**A survey in understanding why the pedestrians and cyclists safety policies are ineffectiveness in Iran** Esfandiar Heidari Kani, Islamic Azad University	**Worker views on safety at roadworks** Ross Blackman, CARRS-Q, Queensland University of Technology	**Symposium: Who is Responsible for Road Safety? Where do the perceptions lie, across all sectors of society, in terms of where each thinks the responsibilities for ensuring best road saftey outcomes? What do we all think, and how can we harness this diversity of opinion to produce best road trauma reduction outcomes?** This session will provide an opportunity for delegates to hear from a variety of sector representatives discussing their take on 'who is responsible for road safety', including: Sharyn Littler, Australian Motoring Enthusiast Party Paul Turner, Executive General Manager Advocacy, RACQ Alton Twine, Director, Engineering Services, City of the Gold Coast, Hon Michelle Hopkins Roberts MLA WA Shadow Minister for Police, Road Safety Additional surprise guests to be announced at the Symposium.
	Enhancing South Australia's Graduated Licensing Scheme Through Road Safety Partnerships and a Strong Evidence Base Paula Norman, Government of South Australia	**NRSPP Workplace Road Safety Guide** Darren Wishart, CARRS-Q, James Newtown, New Zealand Transport Agency	**Using Humour in Peer-Education: Trials and tribulations of an action research project** Bridie Scott-Parker, University of the Sunshine Coast	**The Application of Social Media Strategies to Enhance Enforcement and Road Safety** Sonia Roberts, NSW Police Simon Kelly, Public Safety Business Agency, Queensland	**A Comparison of Road Traffic Crashes along Mountainous and Non-Mountainous Roads in Sabah, Malaysia** Rusdi Rusli, CARRS-Q, Queensland University of Technology	**Driver views on safety at roadworks** Ross Blackman, CARRS-Q, Queensland University of Technology	
	Monitoring Changes from 1999-2014 in the Amount of Supervised Driving Experience Accrued by Victoria Learner Drivers Kelly Imberger, VicRoads	**Panel Session: Examples of good practice translating to a profitable safe business** Ali Abdurrahman, Origin Energy, Greg Smith, Toll NQX Mark Stevens, Uniting Care Australia Rod Baker, Viva Energy	**Students' Response to the RACQ DocuDrama Program** Ioni Lewis, CARRS-Q, Queensland University of Technology	**WA Road Policing Operations - Nimrod Taskforce and Calendar Crackdown** Acting Superintendent Ian Clarke, WA Police	**The Role of Gender and Road Safety in Jordan** Faisal Magableh, UNSW	**Manager's views on safety at roadworks** Tamara Street, CARRS-Q, Queensland University of Technology	
	Are Young Adults' Choice of Travel Mode Changing? Lisa Wundersitz, University of Adelaide				**Reducing Drink Driving in Cambodia: A partnership approach** Sovann Kong, International Alliance for Responsible Drinking (IARD)	**Speeding through roadworks: Understanding driver speed profiles and ways to reduce speeding** Ashim Debnath, CARRS-Q, Queensland University of Technology	
						Evaluation of Safety Treatments at Roadwork Zones Ashim Debnath, CARRS-Q, Queensland University of Technology	

Program Day 2: Thursday 15 October 2015

4.30pm - 6.30pm	**Welcome Reception** **Sponsored By: Tow.com.au** Conference Exhibition Foyer E & F, Upper Level
7.30am	**Registration Opens** Registration Desk, Ground Floor
8.30am - 10.00am	**Conference Opening Plenary** **Sponsored By: Toll Group** Room: Arena 1B
	Official Opening and Welcome by Conference Hosts Mr Lauchlan McIntosh, President, Australasian College of Road Safety; Professor Narelle Haworth, Director, CARRS-Q; Mr Nick Koukoulas, CEO, Austroads Safety Taskforce **Welcome to Country** **Keynote Speaker** Dr Barry Watson, CEO, Global Road Safety Partnership **Keynote Speaker** Mr Gavin Smith, CEO, Bosch Australia
10.00am	**Morning Tea** Conference Exhibition Foyer E & F, Upper Level
10.30am	**Conference Plenary** Room: Arena 1B
10.30am - 11.30am	**Keynote Speaker: Road Safety Advocacy: A bike riding polster's perspective?** Mark Textor, Chairman, Amy Gillet Foundation **How a Diamond Made Trucks Glow in the Dark: 2014 3M-ACRS Diamond Safety Award Winners Report** Marilyn Johnson, Monash University

Concurrent Session 4

11.30am - 1.00pm

Arena 1B	Room 4	Room 5	Room 6	Room 7	Room 8	Room 9
Motorcycle Safety: Protective Clothing	**Symposium: Road Safety in Oman: Understanding developing issues**	**Road Safety Advertising and Communications Sponsored By: Tow.com.au**	**Drink Driving**	**Pre Learner Mentor Programs**	**Off Road and Heavy Vehicles**	**Pedestrian Safety**
Motorcycle Protective Clothing: Physiological and Perceptual Barriers to its Summer Use Liz de Rome, Neuroscience Research Australia	**Building National Capacity in Road Safety Research Within Oman** Abdullah Al-Maniri, CARRS-Q, Queensland University of Technology	**Enhancing the Evaluation of Road Safety Communication Programs: Developing an evaluation strategy** Soames Job, Motor Accident Commission of SA	**The impact of safety measures on the re-offence and crash rates and impact of sanctions in Victoria** Kelly Imberger, VicRoads	**Implementing Best Practice Principles in the Delivery of a Learner Driver Mentor Program in Rural Queensland: A case study report** Tanya Smyth, CARRS-Q, Queensland University of Technology	**Trucks and Road Safety from a Truck Drivers View** Rod Hannifey, TRUCKRIGHT	**Road User Safety Investigation for Pedestrian Priority Zones (Shared Zones) on the Gold Coast** Jess Peters, Point8 Pty Ltd
Impact Abrasion Resistance Quantification of Protective Motorcycle Gloves Christopher Hurren, Deakin University	**Social Influences on Risky Driving Behaviours Among Young drivers in Oman** Hamed Al-Reesi, CARRS-Q, Queensland University of Technology	**Road Policing - Telling It and Selling It: Old Media v New Media** Sonia Roberts, NSW Police Force	**Drink driving among indigenous people in Far North Queensland and Northern NSW: a summary of the qualitative findings** Michelle Fitts, CARRS-Q, Queensland University of Technology	**Learner Driver Mentor Programs: Stakeholder perspectives on an ideal program** Lyndel Bates, Griffith University	**Heavy Vehicle Safety: the role of roadworthiness** Jeff Potter, National Transport Commission	**Speeds and Pedestrians: What's the right mix?** David Healy, DJ Healy Road Safety Consulting
Motorcycle Clothing Fabric Burst Failure During High Speed Impact with an Abrasive Surface Christopher Hurren, Deakin University	**Policing of Road Safety in Oman: Perceptions and beliefs of traffic police officers** Mudhar Al-Mazruii, CARRS-Q, Queensland University of Technology	**Towards Zero and Safety Culture Communications - A new way of engaging with the community** Jessica Truong, Transport Accident Commission	**Left on the Side of the Road? A review of deterrence based theoretical developments in road safety** James Freeman, CARRS-Q, Queensland University of Technology	**Examining Novice Education: What can we learn from a compulsory program delivered to both mature-aged and young pre-learner licence drivers?** Alexia Lennon, CARRS-Q, Queensland University of Technology	**Journey Optimisation by Safest Route** Paul Durdin, Abley Transportation Consultants	**An Explorative Analysis of Pedestrian Situation Awareness at Rail Level Crossings** Gemma Read, University of the Sunshine Coast
Abrasion Resistance of Motorcycle Protective Clothing Worn by Australian Motorcyclists Lauren Meredith, Neuroscience Research Australia	**Socio-Cultural Influences on Vehicle Defects in the Omani Heavy Vehicle Industry** Islam Al-Bulushi, CARRS-Q, Queensland University of Technology	**Mobile in Moreton - Raising the profile of mobility scooter and motorised wheelchair use through community education and awareness** Joanna Broughton, Queensland Police Service			**Trouble in paradise: a systems analysis of beach driving fatalities on Fraser Island (K'Gari)** Nicholas Stevens, University of the Sunshine Coast	

1.00pm - 2.00pm	**Lunch** **Sponsored by: Suncorp**
	Poster Viewing Session with Authors **Sponsored by: BITRE** Conference Exhibition Foyer E & F, Upper Level

	Concurrent Session 5						
	Arena 1B	**Room 4**	**Room 5**	**Room 6**	**Room 7**	**Room 8**	**Room 9**
2.00pm – 3.30pm	**Motorcycle Safety**	**Symposium: Asian Development Bank Package of Actions to Improve Road Safety in ASEAN**	**Road Safety Advertising**	**Drink Driving**	**Older Drivers**	**Heavy Vehicles**	**Workshop: Regulating Supply and Use: Why do we have to choose which regulation to break?**
	Returning Motorcycle Rider Refresher Training in South Australia Paula Norman, Government of South Australia	**ASEAN and ADB Implementing New Approaches to Building Road Safety Capacity** Rob Klein, Asian Development Bank Narelle Haworth, CARRS-Q, Queensland University of Technology Dante Lantin, Asian Development Bank Representative	**Auto Emergency Braking (AEB) – A mass media campaign to increase fitment rates of AEB in Victoria, Australia** Samantha Buckis, Transport Accident Commission	**Drink Driver Rehabilitation and New Developments** Gavan Palk, CARRS-Q, Queensland University of Technology	**Predictors of Older Drivers' Looking Behaviour when Negotiating Intersections** Nadine Richter, Monash University Accident Research Centre	**Safety Culture and Speeding in the Australian Heavy Vehicle Industry** Jason Edwards, CARRS-Q, Queensland University of Technology	**Workshop: Regulating Supply and Use: Why do we have to choose which regulation to break?** Eric Chalmers, Kidsafe ACT Ian Scott, ACCC
	Development of Victoria's New Motorcycle Graduated Licensing System Teresa Senserrick, University of NSW	**Developing the ASEAN Regional Road Safety Strategy** Narelle Haworth, CARRS-Q, Queensland University of Technology	**NSW Level Crossing Awareness and Enforcement Campaign: Four years of working together** Michael Timms, NSW Police Force	**Enhancing Offender Programs to Address Recidivism** Chris Harrison, Road Trauma Support Services Victoria	**Longitudinal Patterns in Older Drivers' Speeding Behaviour** Anna Chevalier, The George Institute for Global Health, The University of Sydney	**Chain of Responsibility and the Heavy Vehicle Freight Industry: benefits, challenges and opportunities** Sarah Jones, Toll Group	
	The Effect of the 100% Motorcycle Helmet Use Campaign on Motorcyclist Head Injuries in Thailand Jake Olivier, University of NSW	**Developing a New Index for Comparing Road Safety Maturity: Case study of the ASEAN Community** Oscar Oviedo Trespalacios, CARRS-Q, Queensland University of Technology	**Helping Motorcyclists 'Ride to Live': Developing a large scale public education campaign for motorcyclists using research and stakeholder consultation** Lauren Fong, Transport for NSW	**The New Zealand Alcohol Interlock Program: A review of its first year as a sentencing option** Gerald Waters, Researching Impaired Driving In New Zealand	**Behind the Wheel: A randomised controlled trial evaluating a safe transport program for older drivers** Lisa Keay, The George Institute for Global Health, The University of Sydney	**Evidence that Truck Driver Remuneration is Linked to Safety Outcomes: a review of the literaure** Lori Mooren, University of NSW	
	Infrastructure improvements to reduce motorcycle crash risk and crash severity David Milling, ARRB Group Ltd	**Strengthening Local Road Safety Capacity in Cambodia** Socheata Sann, CARRS-Q, Queensland University of Technology	**What's the Ride Answer? Australia must take a more integrated approach to motorcycle safety** Shaun Lennard, Australian Motorcycle Council	**Expanding the Victorian Alcohol Interlock Program to All Convicted Drink Drivers** Chris Freethy, VicRoads	**Older Drivers' Perceptions and Acceptance of Vehicle Safety Technology** Tim Davern, RACV	**Heavy Vehicle Driver Fatigue: evidence based policy making** Nick Fisher, National Transport Commission	
3.30pm	**Afternoon Tea** Conference Exhibition Foyer E & F, Upper Level						

	Concurrent Session 6						
	Arena 1B	**Room 4**	**Room 5**	**Room 6**	**Room 7**	**Room 8**	**Room 9**
4.00pm – 5.30pm	**Motorcycle Safety**	**Road Safety in Low and Middle Income Countries**	**Community Road Safety Sponsored By: Queensland Government**	**Drug Driving**	**Older Drivers - Fitness to Drive**	**Symposium: Driving Heavy Vehicle Safety Through Technology: challenges, results and lesson learned at Toll Group**	**Road Safety Management and Strategy**
	Drivers' Attitudes and Knowledge Regarding Motorcycle Lane Filtering Practices Immediately Preceeding the ACT Lane Filtering Trial Vanessa Beanland, The Australian National University	**Road Safety Challenges and Opportunities in Tamil Nadu** Martin Small, Martin Small Consulting	**"Stay on Track Outback" Road Safety Education Project** Sarah Garyson and Juliet McGrath, Queensland Police Service	**Drink and Drug Driving in Australian Young Adult Users and Non-Users of Illicit Stimulants** Andrew Smirnov, University of Queensland	**Elderly Drivers and Emergency Department Visits** Herbert Chan, University of British Columbia	**Driving heavy vehicle safety through technology: challenges, results and lessons learned at Toll Group: The driver excellence program at Toll Linehaul & Fleet Services** Anita Douglas, Toll Group	**Towards Zero: Building a safe road system for Victoria** Jessica Truong, Transport Accident Commission
	Characteristics of Road Factors in Multi and Single Vehicle Crashes in Queensland Yusuf Adinegoro, CARRS-Q, Queensland University of Technology	**Traffic Behaviour and Compliance with the law in Low and Middle Income Countries: Are we observing 'pragmatic driving'?** Mark King, CARRS-Q, Queensland University of Technology	**Building Community Capacity for Road Safety: Are we doing it?** Terri-Anne Pettet, WA Local Government Association	**The incidence and characteristics of illicit drug related driver fatalities in Western Australia, 2000 - 2012** Peter Palamara, Curtin University	**Older Road User Safety: Identifying needs and gaps in health professionals' communication with older patients about fitness to drive** Nina Pereira, VicRoads	**Driving heavy vehicle safety through technology: challenges, results and lessons learned at Toll Group: A contextual overview** Sarah Jones, Toll Group	**A Road Safety Strategy for Norfolk Island: An Australian external territory** Ian Faulks, CARRS-Q, Queensland University of Technology
	The Austroads In-depth Case Control Study of Motorcycle Crashes in NSW: Causal relationship findings Julie Brown, Neuroscience Research Australia	**Empirical Analysis of Speeding Behaviour and Determining Speed Limits for Bicycles** Cheng Xu, Zhejiang Police College	**Onslow Road Users Group Taking Action Together: Making a difference** Karen White, WA Local Government Association	**Drug Driving in NSW: Evidence gathering, enforcement and education** Ralston Fernandes, Transport for NSW	**Determining Fitness to Drive for Older and Cognitively Impaired Drivers: DriveSafe DriveAware a Touch Screen Test for Medical Practice** Beth Cheal, Pearson/ The University of Sydney	**Driving heavy vehicle safety through technology: challenges, results and lessons learned at Toll Group: Driver State Sensing (DSS) machines at Toll Resources and Government Logistics** Bill Law, Toll Group	**Who's in Control of the Fatal Five? A systems analysis of Queensland's road transport system** Paul Salmon, University of the Sunshine Coast
		Observations of Road Safety Behaviours and Practices of Motorcycle Rickshaw Drivers in Lahore, Pakistan Muhammed Tahir, CARRS-Q, Queensland University of Technology	**Car v House Crashes: Victims tell their story** Catherine Ferguson, Edith Cowen University Karen White, WA Local Government Association		**Older Adults and Driving Reduction: Is the Gender Gap Narrowing?** Heidy Hassan, CARRS-Q, Queensland University of Technology	**Driving heavy vehicle safety through technology: challenges, results and lessons learned at Toll Group: In-truck cameras at Toll NQX** Greg Smith, Toll Group	**Greater Undestanding of Rear-end Crashes in a Safe System** Chris Jurewicz, ARRB Group Pty Ltd
6.30pm - 10.30pm	**Conference Dinner** **Sponsored By: Queensland Government** **Includes presentation of the 3M-ACRS Diamond Road Safety Award and ACRS Fellowship** Hall 4, Gold Coast Convention and Exhibition Centre						

Program Day 3: Friday 16 October 2015

7.30am	**Registration Opens** Registration Desk, Ground Floor
8.30am – 10.00am	**Conference Plenary** Room: Arena 1B
	Welcome and Recap of Previous Day
	Keynote Speaker Professor Brian Owler, President, Australian Medical Association **Facilitated Panel Discussion: Injury, Rehabilitation and Risk** Professor Brian Owler, Australian Medical Association Professor Gerry FitzGerald, Queensland University of Technology Professor James Harrison, National Injury Surveilance Unit, Flinders University
10.00am	**Morning Tea** Conference Exhibition Foyer E & F, Upper Level
10.30am	**Conference Plenary** Room: Arena 1B
10.30am-11.30am	**Status of Road Safety at the Australian and New Zealand Level** Mr Mark Bailey MP, Minister for Main Roads, Road Safety and Ports, Queensland Parliament Mr Bernard Carlon, Acting General Manager, NSW Centre for Road Safety Mr Ernst Zollner, Director of Road Safety, New Zealand Transport Agency

11.30am – 1.00pm

Concurrent Session 7

Arena 1B	Room 4	Room 5	Room 6	Room 7	Room 8	Room 9
Characteristics and Profiling of Speeding Offenders	**Symposium: World Ban and iRAP - How to halve road deaths and injuries by 2020 across the Asia Pacific Region - and how you can help!**	**Fatigue**	**Symposium: VicRide: Development and Evaluation of an On-road Motorcycle Coaching Program for Novice Riders**	**Using Data for Road Safety Benefits**	**Speed Analysis and Enforcement**	**Child Occupant Protection**
Too Fast for These Conditions? Factors influencing drivers' choice of speed Samuel Charlton, University of Waikato	**Road safety – an essential element of all road improvement projects** Chris Bennett, World Bank Sydney	**Understanding Drivers Motivations to Take a Break When Tired** Ann Williamson, University of NSW	**Assisted Rides - A large-scale trial of a motorcycle coaching program** Mark Russell, VicRoads	**How Serious Are They? The use of data linkage to explore different definitions of serious crash injuries** Angela Watson, CARRS-Q, Queensland University of Technology	**Determinants of Road Traffic Safety: New evidence from Australia using a State-space analysis** Son Nghiem, Queensland University of Technology	**Restraining children with disabilities or medical conditions safely** Susan Teerds, Kidsafe QLD
Profile of the Speeding Driver: Examination of driver attitudes and behaviours around posted speed limits on Australian roads Amanda Stephens, Monash University Accident Research Centre	**World Bank support to Road Safety in India: Evolving trends and approaches** Rajesh Rohatgi and Sri Kuman Tadimalla, World Bank, India	**Signs of Driver Sleepiness and Risky Sleepy Driving Behaviours: The association with demographic, work and sleep related factors** Christopher Watling, CARRS-Q, Queensland University of Technology	**Development and Evaluation of an On-ride Motorcycle Coaching Program in Victoria: How Well was VicRide Implemented and Received by the Target Novice Motorcycle Riders?** Chika Sakashita, The George Institute for Global Health, The University of Sydney	**An Inexpensive Technical Solution for Studying Vehicle Separations Within Real Traffic Flows Using On-board Sensors** Jamie Mackenzie, University of Adelaide	**An Analysis of Driver Behaviour Through Rural Curves: Exploratory Results on driver speed** Blair Tuner, ARRB Group Ltd	**Accommodation of low birth rate babies in dedicated and convertible rearward facing child restraint systems** Julie Brown, NeuRA
Criminal Histories of Crash and non-crash involved Queensland speeding offenders: Evidence supporting the idea that we drive as we live Judy Fleiter, CARRS-Q, Queensland University of Technology	**Bank's development of open source software and the Data for Road Incident Visualization Evaluation and Reporting (DRIVER) platform** Chris De Serio, World Bank, Washington D.C.	**In-vehicle Filming of Driver Fatigue on YouTube: vlogs, crashes and bad advice** Ashleigh Filtness, CARRS-Q, Queensland University of Technology	**Effectiveness of an On-road Motorcycle Rider Coaching Program: A randomised control trial** Rebecca Ivers, The George Institute for Global Health, The University of Sydney	**The Australian Naturalistic Driver Study: from beginnings to launch** Raphael Grzebieta, University of NSW	**Proposed vehicle impact speed - severe injury probability relationships for selected crash types** Chris Jurewicz, ARRB Group Pty Ltd	**Dynamic Assessment of Aftermarket Child Restraint Accessories: Are there any safety implications?** Tim Davern, RACV
	Maximising travel on 3-star or better roads – Global results from over 500,000km of roads Rob McInerney, International RoadAssessment Programme			**Using the Critical Decision Method and Decision Ladders to analyse traffic incident management system issues** Vanessa Cattermole, University of Queensland		**Exploring the sale of second hand child restraints and booster seats in Victoria** Elvira Lazar, RACV
	Panel Discussion **Session speakers** Soames Job, Global Road Safety Solutions Luke Rogers, International Road Assessment Programme					

Time	Arena 1B	Room 4	Room 5	Room 6	Room 7	Room 8	Room 9
1.00pm - 2.00pm	**Lunch**						
	Concurrent Session 8						
	Arena 1B	**Room 4**	**Room 5**	**Room 6**	**Room 7**	**Room 8**	**Room 9**
	Speed Cameras and Enforcement	**Workshop and Discussion: Pacific Road Safety Project Design**	**Vehicle Safety Sponsored by RACQ**	**Technology**	**Using Data for Road Safety Benefits**	**Road Safety Management and Strategy**	**Symposium: MUARC-TAC Enhanced Crash Investigation Study**
2.00pm – 3.15pm	**Review of South Australia's Fixed and Mobile Speed Camera Programs** Phoebe Maxwell, South Australia Police	**Workshop and Discussion: Pacific Road Safety Project Design** Conference delegates are invited to an interactive workshop session to share their experience and expertise in helping shape a comprehensive World Bank funded road safety project for the Pacific Region.	**Contribution of vehicle safety improvements and infrastructure investment on reducing road trauma in Victoria and projected future benefits** Angelo D'Elia, Monash University Accident Research Centre	**The Future of Road Safety in a Technological World: How will technology impact the practice of road safety** Paul Tyler, National ICT Australia	**A Road Safety Risk Prediction Methodology for Low Volume Rural Roads** Dale Harris, Abley Transportation Consultants	**Safer Transport for a Safer Community: Development and implementation of the Coast Road Safety Plan 2015-2020** Matthew Tilly, City of Gold Coast	**A platform to understand the causes and consequences of serious injury crashes** Michael Fitzharris, Monash University Accident Research Centre
	Reduction of Speed Limit from 110km/h to 100km/h on Certain Roads in South Australia: A follow up evaluation Jamie Mackenzie, University of Adelaide		**Emerging vehicle safety technologies and their potential benefits: Discussion of expert opinions** Giulio Ponte, The University of Adelaide	**Security Issues for Future Intelligent Transport Systems (ITS)** Ernst Foo, Queensland University of Technology	**Do Motor Vehicle Crashes Arise from Single or Multiple Unique Risk Processes? An inquiry into crash causes and modelling** Amir Pooyan Afghari, Queensland University of Technology	**Use of Improved Evidence on Aboriginal Road Trauma to Develop and Deliver the NSW Aboriginal Road Safety Action Plan** Andrew Graham, NSW Centre for Road Safety	**Incidence and patterns of lower extremity injuries sustained during frontal offset crashes** Marnie Reilly, Monash University Accident Research Centre
	Rapid Deployment of Intelligent Speed Adaption in New South Wales - The Story of Speed Advisor John Wall, NSW Centre for Road Safety		**Laser Ablated Removable Car Seat Covers for Reliable Deployment of Side-torso Airbags** Arun Vijayan, RMIT University	**Autonomous Vehicles: Human Factors, Issues and Future Research** Jerome Carslake, ARRB Group Ltd	**A Practical Methodology Using in-depth Crash Data to Support the Assessment of New Motorcycle Safety Technologies** Trevor Allen, Monash University Accident Research Centre	**Safe System Roads for Local Government** Aaron Campion, GHD	**Using event data recorders and simulated crash reconstructions in the analysis of crash causation** Sujanie Peiris, Monash University Accident Research Centre
3.15pm – 4.00pm	**Conference Awards** **Farewell and Thank You**						
4.00pm	**Conference Ends**						

Characteristics of road factors in multi and single vehicle motorcycle crashes in Queensland

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Abstract

Motorcyclists were involved in 6.4% of all police-reported crashes and 12.5% of all fatal crashes in Queensland during 2004-2011. Of these crashes, 43% were single-vehicle (SV) and 57% were multi-vehicle (MV). The overall reduction in motorcycle crashes in this period masked different trends: single-vehicle crashes increased while MV motorcycle crashes decreased. However, little research has been undertaken to understand the similarities and differences between SV and MV motorcycle crashes in Queensland and the factors underlying these diverging trends. The descriptive analyses and regression model developed here confirm international research findings regarding the greater role of road infrastructure factors in SV crashes. In particular, road geometric factors such as horizontal and vertical alignment and road surface factors such as sealed/unsealed and wet/dry were more important in SV than MV crashes.

Introduction

Globally there has been a significant increase in the number of motorcycles (Haworth, 2012; Rogers, 2008). In Australia, the number of motorcycles increased 8.2% per year between 2006 and 2010. Despite comprising only 4.3% of registered vehicles, motorcycles were involved in 15.8% of total fatal crashes in 2011 (ABS, 2012). Motorcycles have a higher risk of being involved in serious crashes than other vehicles and motorcyclists are more vulnerable to injury (DFT, 2008; Hurt, Ouellet, & Thom, 1981).

Many authors have commented that road infrastructure factors (geometry and surface condition) play a larger role in the occurrence (ACEM, 2004; Haworth, Smith, Brumen, & Pronk, 1997; Saleh et al., 2010) and severity (Elslande et al., 2013) of motorcycle crashes than in crashes of four-wheeled vehicles. The geometric characteristics of roads that can contribute to crash occurrence include minimum stopping sight distance, minimum horizontal radius, minimum crest vertical curves, and maximum superelevation (Hall et al., 2009; Underwood, 1991). Motorcycle crashes frequently occur on curves and descending gradients (Saleh et al., 2010; Yannis, Vlahogianni, Golias, & Saleh, 2010). Curves are not only associated with the highest crash risk but also the highest severity level for motorcycle crashes (Blackman & Haworth, 2013; Clarke, Ward, Bartle, & Truman, 2005; Mohammad, Tay, & de Barros, 2012).

Road surface characteristics also play an important role in motorcycle safety. Typical road surface characteristics include road-based hazardous objects, deformation, cracking, texture, edge defect, potholes, patches, and skid resistance (Austroads, 2012). Road-based hazards such as gravelled road shoulders, slippery road markings, slippery manhole covers plates and uneven road surfaces increase the crash risks for motorcyclists (Haworth, Symmons, & Kwadlo, 2000; Miller, 1997). Surface irregularities such as unclean road or loose material, poor road condition or road markings also increase motorcycle crash risk (Haworth, 1999;

Haworth et al., 1997). Wet bitumen for road surface repairs can cause steering problems for motorcyclists which can lead to a crash (Elliott et al., 2003; Huang & Preston, 2004).

International studies have shown road factors such as road geometry and road surface defects to be common in single vehicle (SV) motorcycle crashes (Hurt et al., 1981; Saleh et al., 2010). Many fatal motorcycle crashes involve the rider losing control and running off the road, falling from the motorcycle, and hitting road obstacles (Jama, Grzebieta, Friswell, & McIntosh, 2011; Preusser, Williams, & Ulmer, 1995). Previous comparisons of SV and MV motorcycle crashes have demonstrated differences in the locations of these crashes. SV motorcycle crashes more commonly occurred on non-arterial roads, rural roads, two lane roads, mid-block, and roads with high speed zones (Chang & Yeh, 2006; Diamantopoulou, Brumen, Dyte, & Cameron, 1995; Johnston, Brooks, & Savage, 2008; Saleh et al., 2010). In contrast, intersections, merging, turning areas, and mid-block locations were common in MV crashes (ACEM, 2004; Haque, Chin, & Debnath, 2012). Stationary objects were more likely to contribute to the severity of injury and damage in SV crashes (Quddus, Noland, & Chin, 2002). A US analysis of the severity of SV motorcycle crashes showed that wet pavement with no rain falling was common in SV crashes but that the severity of these crashes tended to be limited to property damage (Shankar & Mannering, 1996). Interstate freeways with high-speed traffic with adequate radii on curves and sufficient sight distance on grades were the safest roadways (Shankar & Mannering, 1996).

The aim of this paper is to explore the similarities and differences between MV and SV motorcycle crashes in order to provide a preliminary assessment of the importance of road factors in motorcycle crashes in the Australian riding environment.

Method

Study Approach

To understand the similarities and differences between SV and MV motorcycle crashes, a descriptive analysis was first undertaken to understand the characteristics of these crashes in term of road factors and environment factors. A regression model was then developed which estimated the relative likelihood of SV and MV motorcycle crashes for different characteristics of crashes, road factors, and environment. Crashes such as hit fixed/temporary object or fall from vehicle were coded as SV crashes if no vehicle other than the motorcycle was involved. Those crashes which involved another vehicle were coded as MV crashes. Types of multi vehicle crashes included angle, sideswipe, rear-end, and head-on crashes.

Data

Crash data were acquired from the Department of Transport and Main Roads for the period 1 January 2004 to 31 December 2011. Crash severity was coded by police as fatal, hospitalisation, medical treatment, and minor injury. Data after 2011 were incomplete for crashes of severity levels lower than hospitalisation so it was decided not to analyse the later data. Property damage only crashes were excluded because of high levels of under-reporting of these crashes. The final dataset contained 12,657 crashes of which 57% were MV crashes (n=7,202) and 43% were SV crashes (n=5,455). Lighting conditions were recorded 'unknown' in the 0.04% of MV crashes and 0.07% of SV crashes. Road surface conditions were recorded as 'unknown' in 0.01% of MV crashes and 0.07% of SV crashes.

Regression Model

A regression model was formulated to examine the similarities and differences between MV and SV motorcycle crashes. By using the two types of crashes (MV = 1, SV =0) as a response variable, a Binary Logistic Model (BLM) can be well formulated. A set of explanatory variables describing the characteristics of crashes, road factors, and environment (Table 1) which were hypothesised to be associated with the likelihood of MV and SV motorcycle crashes was included in the model. To identify the subset of explanatory variables which yield the most-parsimonious model, a backward elimination procedure was employed to remove the non-significant variables one by one so that the Akaike Information Criteria (AIC) was minimized. In order to evaluate if the model has sufficient explanatory power, the likelihood ratio statistics (G^2) was used.

Result

Descriptive statistics

The characteristics of the 12,657 motorcycle crashes are summarized in Table 1. Figure 1 shows that the numbers of both MV and SV crashes increased from 2004 until 2008, then decreased until 2011. The rate of decrease for MV crashes appeared to be higher than that for SV crashes. During 2008-2011, the number of registered motorcycle has increased from 139,355 to 156,825 (Queensland Government, 2015). It suggests that exposure of motorcyclists might have increased, whereas the number of crashes have decreased. SV crashes were more likely to occur during weekends (41% vs. 23%) and night periods (25% vs. 18%) than MV crashes.

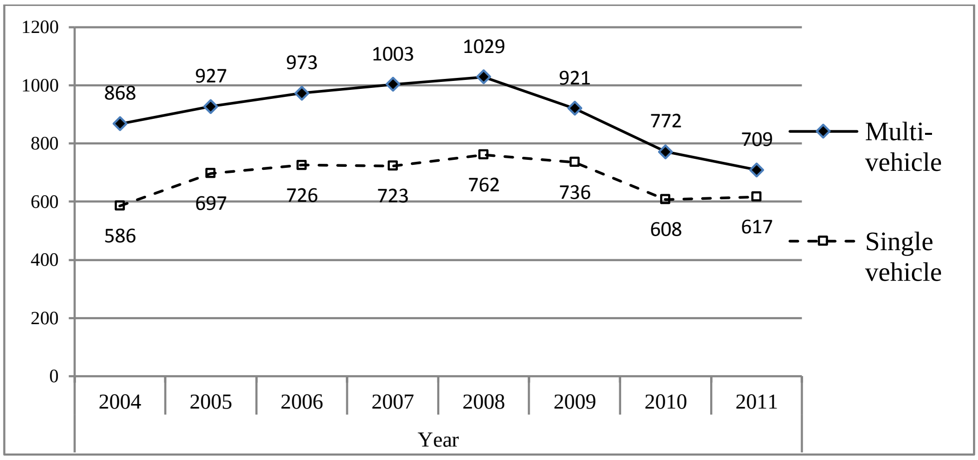

Figure 1 Multi and single motorcycle crashes in Queensland between 2004 and 2011

Most MV (61%) and SV crashes (46%) occurred on roads with a 60 km/h speed limit. On roads with posted speed limits of 80 km/h and above, SV crashes occurred more often than MV crashes (80-90 km/h: 13% vs. 7%; 100-110 km/h: 19% vs. 7%). MV crashes were more likely to occur at straight sections (84% vs. 54%), but less likely to occur at curves with both obstructed view (5% vs. 16%) and open view (11% vs. 29%). There were more MV crashes on level roadways (77% vs. 64%), but less on roadways with grade (15% vs. 24%) than SV crashes. Most crashes occurred on dry sealed pavement roads (MV: 92%, SV: 84%), wet sealed pavement roads had a greater share of SV crashes (12%) than MV crashes (7%). As expected, a larger proportion of MV than SV crashes occurred at intersections with give way, stop, and traffic signal controls. The injury severity patterns of the crashes showed that the majority resulted in hospitalisation (MV: 50%; SV: 57%) or medical treatment (MV: 31%; SV: 27%).

Regression model results

The parameter estimates, odds ratios (O.R.), and their statistical significance were obtained using the maximum likelihood estimation method in STATA 13.1 (Table 1). The backward elimination process removed two non-significant variables (crash month and atmospheric condition) from the most-parsimonious model that yielded an AIC value of 14,702. The likelihood ratio statistics of the resulting model was 2670 (34 df), which was well above the corresponding critical value for significance at 99% confidence level.

In 2011 (relative to 2007), MV crashes were significantly less likely (16.8% lower odds) to occur than SV crashes. MV crashes were less likely than SV crashes to occur on weekends (O.R. = 0.58) and during night hours (O.R. = 0.63). Similarly, the odds of MV crashes occurring in darkness with no street lighting were 41% lower than SV crashes (relative to daylight).

MV crashes were less likely than SV crashes to occur in both low speed zones (15.5% lower odds in 50 km/h or less roads) and high speed zones (80-90 km/h: 35.6% lower odds; 100-110 km/h: 50.7% lower odds) compared to 60 km/h speed zones. MV crashes were also less likely than SV crashes to occur on curves where the view was obstructed (68.6% lower odds) and open (69.7% lower odds) compared to straight road sections. Relative to level road sections, MV crashes were less likely than SV crashes to occur on dips (27.9% lower odds) and grades (16.2% lower odds).

Relative to dry sealed roads, the odds of MV crashes occurring on wet sealed roads were 53% lower than SV crashes. Similarly, the odds of MV crashes occurring on unsealed roads under both wet (O.R. = 0.22) and dry conditions (O.R. = 0.53) were lower compared to dry sealed roads. Relative to locations with no traffic control, MV crashes were more likely than SV crashes at locations with give way sign (142% increase in odds), stop sign (338% increase in odds), and traffic lights (140% increase in odds).

Relative to the crashes resulting in hospitalisation injury, the odds of MV crashes to produce fatal injury and minor injury were 39.7% and 25.7% higher, respectively, than SV crashes.

Table 1. Descriptive statistics and logistic regression model for the multi and single vehicle motorcycle crashes

Explanatory variables	**Descriptive statistics**		**Logistic Regression**				
	Multi-vehicle	**Single-vehicle**	**Beta**	**O.R.**	***p***	***95% of CI***	
	% (N=7202)	% (N=5455)				*Lower*	*Upper*
Constant			0.966		<0.001	2.301	2.996
Year							
2004	12.1	10.7	0.06	1.062	0.458	0.906	1.244
2005	12.9	12.8	-0.032	0.968	0.679	0.830	1.129
2006	13.5	13.3	-0.049	0.952	0.525	0.818	1.107
2007*	13.9	13.3					
2008	14.3	14	0.0004	1	0.996	0.860	1.161
2009	12.8	13.5	-0.098	0.907	0.208	0.778	1.056
2010	10.7	11.1	-0.058	0.944	0.478	0.804	1.107
2011	9.8	11.3	-0.184	0.832	0.024	0.708	0.976

Explanatory variables	Descriptive statistics		Logistic Regression				
	Multi-vehicle	**Single-vehicle**	**Beta**	**O.R.**	***p***	***95% of CI***	
	% (N=7202)	% (N=5455)				*Lower*	*Upper*
Day of week							
Weekday*	76.9	59					
Weekend	23.1	41	-0.544	0.581	<0.001	0.532	0.633
Time period							
Day (6 am - 6 pm) *	82	74.9					
Night (6 pm - 6 am)	18	25.1	-0.456	0.634	<0.001	0.522	0.770
Speed limit zone (km/h)							
≤ 50	18.5	17.2	-0.168	0.845	0.002	0.760	0.940
60 *	60.9	46					
70	6	4.7	0.012	1.012	0.892	0.848	1.209
80 - 90	7.2	12.9	-0.439	0.644	<0.001	0.561	0.740
100 - 110	7.4	19.1	-0.708	0.493	<0.001	0.433	0.561
Lighting condition							
Darkness - Lighted	13.6	15.6	-0.062	0.94	0.562	0.761	1.160
Darkness - Not lighted	2	6.5	-0.532	0.587	<0.001	0.445	0.776
Dawn/Dusk	6.6	5.6	0.136	1.146	0.144	0.954	1.375
Daylight *	77.7	72.2					
Unknown	0.04	0.1	-0.469	0.626	0.597	0.110	3.552
Horizontal alignment							
Curved - view obscured	5.1	16.3	-1.159	0.314	<0.001	0.271	0.363
Curved - view open	11	29.4	-1.196	0.303	<0.001	0.273	0.335
Straight *	83.9	54.3					
Vertical alignment							
Crest	5.4	6.9	0.015	1.015	0.864	0.856	1.202
Dip	2.5	4.7	-0.328	0.721	0.004	0.578	0.899
Grade	15	24.1	-0.176	0.838	0.001	0.754	0.932
Level *	77	64.3					
Road surface condition							
Sealed - Dry *	92	83.7					
Sealed - Wet	6.7	12.1	-0.752	0.472	<0.001	0.411	0.541
Unknown	0.02	0.1	-1.819	0.162	0.116	0.017	1.565
Unsealed - Dry	1.2	3.6	-0.639	0.528	<0.001	0.399	0.697
Unsealed - Wet	0.1	0.5	-1.501	0.223	0.001	0.090	0.552
Traffic control Type							
Give way	18.9	8	0.882	2.415	<0.001	2.135	2.733
No control *	61.9	85.4					
Stop sign	5.1	1.2	1.478	4.383	<0.001	3.309	5.805
Operating traffic lights	13.8	5	0.875	2.399	<0.001	2.067	2.785
Others	0.3	0.3	0.04	1.04	0.907	0.538	2.011
Crash severity							
Fatal	3.1	4.2	0.334	1.397	0.002	1.127	1.733
Hospitalisation *	49.8	56.7					
Medical treatment	30.8	27.4	0.025	1.026	0.588	0.936	1.123
Minor injury	16.4	11.8	0.229	1.257	<0.001	1.115	1.417
Summary statistics							
Number of observation	12657						
Log-likelihood (at zero)	-8652.21						
Log-likelihood (at model)	-7317.01						
AIC	14702.03						
G^2	2670.40 (34 *df*)						
	P <0.001						

* Reference category

Discussion

Both MV and SV motorcycle crashes peaked in the year 2008 with increasing trends since 2004, but have decreased since 2008, suggesting that the safety of motorcyclists has improved in the recent years. While such improvements are encouraging, greater reductions were seen in the numbers of MV crashes than the SV crashes. The differences in reduction of crash numbers warrant more research on understanding the safety issues in MV and SV motorcycle crashes.

The finding that SV motorcycle crashes are more likely to occur during weekends than MV crashes was in consistent with other studies (e.g., Haworth et al., 1997). Weekend riding is generally for recreational purposes rather than commuting purposes (Johnston et al., 2008; Moskal, Martin, & Laumon, 2012) which might be a possible explanation for observing the greater likelihood of SV crashes. Roads in rural area are very common for touring activities. The current study shows that single motorcycle crashes were common on rural roads. This is consistent with the findings of Saleh et al. (2010) that outside urban areas the most frequent collision type is a SV crash (run-off the road).

SV crashes were more likely than MV crashes to occur during night hours and on roads without street lighting. Motorcyclists rely on single headlamps and retroreflective materials from road marking or guide post, therefore riders may take longer to detect any hazardous road conditions such as wet surface, debris or potholes. Haworth et al. (1997) found that about one-quarter occurred under difficult lighting conditions including night-time. They indicated that SV crashes were more likely than MV crashes to occur at night.

SV crashes were more likely to occur on curves than MV crashes. This finding was consistent with earlier research by Schneider, Savolainen, and Moore (2010) who found that horizontal curves significantly influenced the frequency of SV motorcycle crashes. More importantly, SV crashes on rural roads segments have been shown to have higher likelihoods to be fatal than on urban roads (Chang & Yeh, 2006; Saleh et al., 2010). Quddus et al. (2002) further demonstrated that crashes at bends may result in motorcyclist leaving the carriageway and overturning onto off-road stationary objects such as a guardrail, rocks or trees and increasing the probability of being fatal. ACEM (2004) noted that a roadway design defect such as curve with decreasing radius was considered to be a condition which presented a danger to riders. Riders could experience difficulties in maintaining the control of their motorcycles while manoeuvring or negotiating a sharp curve.

Descending gradients have been identified as critical factors in both MV and SV crashes (Saleh et al., 2010). The current research found that SV crashes were more likely to occur on descending gradients than MV crashes. On steep downgrades, the acceleration will increase and the front wheel will be carrying most of the weight. Limebeer, Sharp, and Evangelou (2001) found that the wobble mode becomes significantly less stable under braking and the effects become exaggerated as the deceleration rate increases. Hurt et al. (1981) found that wobble, unstable oscillatory motion of the motorcycle front mass is the most common loss of control mode in SV crashes.

Single motorcycle crashes were more likely to occur on roads with 80 km/h or more speed limits. The 80+ km/h roads are generally the highways and motorways where there are fewer intersections than roads with 60 km/h limits (mostly urban and sub-urban roads), which could possibly suggest that there are less numbers of conflicts in these roads than the urban 60 km/h roads. Elliott et al. (2003) found that SV motorcycle crashes involve larger machines which are ridden more often on high-speed rural roads than smaller machines. However, they are not confident with the outcome unless the distance ridden for different engine capacities are included the analysis. Engine size does not emerge as a risk factor in a number of studies (Haworth, Blackman, Rolison, Hewson, & Hellier, 2013; Langley, Mullin, Jackson, & Norton, 2000; Van Honk, Klootwijk, & Ruijs, 1997). The possible explanations are rider speeding behaviour (Elliott et al., 2003) and active safety system technology (Antilock Braking System) reliability for motorcycle (Burton, Delaney, Newstead, Logan, & Fildes, 2004), whilst a further observation is required.

The analysis demonstrated that road surface condition influenced the relative probability of SV motorcycle crashes. Compared to dry sealed roads, SV crashes were more likely to occur on wet roads (both sealed and unsealed) and dry unsealed roads than MV crashes. These findings suggest that riders' inability to control motorcycles on rough and slippery surfaces could often lead to causing out-of-control or leaving-carriageway types of crashes. Furthermore, earlier research showed that riders are likely to reduce speed as they compensate for the increased risk of riding when the road surface is wet (Quddus et al., 2002; Savolainen & Mannering, 2007).

MV crashes are more likely to occur than SV crashes at locations where the give way, stop sign, and traffic lights controls are present. Conflicts involving vehicles from different directions are likely to occur in these locations. Therefore, it was not surprising to see that MV crashes were more common at these locations. Preusser et al. (1995) found that ran traffic control crashes in intersections (72%) occur when one vehicle with an obligation to stop, remain stopped, or yield, fails to do so and thus collides with other vehicles.

The higher likelihood of fatality in MV crashes than in SV crashes may reflect the greater impact force resulting from two or more road users in MV crashes. Drivers find it difficult to estimate the speed of approaching motorcycles because they are less conspicuous (Gould, Poulter, Helman, & Wann, 2012; Thomson, 1980). Motorcycles that are further away have a smaller apparent size in other road user's vision (Clabaux et al., 2012) and therefore if they are travelling at a high speed, the time to react to changes is shorter. Walton and Buchanan (2012) indicated that motorcycles are generally faster than the other traffic in the intersection, thereby increasing their odds of creating the conditions for a crash. To conclude, earlier research showed the likelihood of rider being injured is extremely high: in 98% of multi-vehicle crashes and injury severity increases with speed and motorcycle size (Hurt et al., 1981).

This paper explores the similarities and differences both the effects of road and environment factors on MV and SV motorcycle crashes. However, it is acknowledged that other factors such as rider and vehicle characteristics might have significant effects on the crashes. Examining the effects of these factors was beyond the scope of the current study.

Conclusion

Although the explanatory variables included in the regression were limited to those features of the road elements that are recorded in police crash data, the findings are consistent with earlier research that showed the importance of road factors such as geometry and road surface, and environment factors such as lighting condition in single motorcycle crashes.

The greater importance of road and environment factors in SV crashes underlines the need to improve road infrastructure to reduce the occurrence and severity of motorcycle crashes.

Further research is needed to gain a more comprehensive understanding of the appropriate treatments to reduce the risks associated with the factors identified in this study. More detailed information such as road design (e.g., curve radii, descending grade) and road surface condition (e.g., skid resistance, unevenness) at crash sites will be collected in later studies in order to better estimate the quantitative contributions of these factors.

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Do Motor Vehicle Crashes Arise from Single or Multiple Unique Risk Processes? An Inquiry into Crash Causes and Modelling

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Abstract

Crashes at any particular transport network location consist of a chain of events arising from a multitude of potential causes and/or contributing factors whose nature is likely to reflect geometric characteristics of the road, spatial effects of the surrounding environment, and human behavioural factors. It is postulated that these potential contributing factors do not arise from the same underlying risk process, and thus should be explicitly modelled and understood. The state of the practice in road safety network management applies a safety performance function that represents a single risk process to explain crash variability across network sites. This study aims to elucidate the importance of differentiating among various underlying risk processes contributing to the observed crash count at any particular network location. To demonstrate the principle of this theoretical and corresponding methodological approach, the study explores engineering (e.g. segment length, speed limit) and unobserved spatial factors (e.g. climatic factors, presence of schools) as two explicit sources of crash contributing factors. A Bayesian Latent Class (BLC) analysis is used to explore these two sources and to incorporate prior information about their contribution to crash occurrence. The methodology is applied to the state controlled roads in Queensland, Australia and the results are compared with the traditional Negative Binomial (NB) model. A comparison of goodness of fit measures indicates that the model with a double risk process outperforms the single risk process NB model, and thus indicating the need for further research to capture all the three crash generation processes into the SPFs.

Introduction

Efficient management of resources allocated to reduce dramatic costs of vehicular crashes requires an in-depth understanding of crash causation process. It is widely accepted that crashes at any particular location of the transport network are the results of a single chain of events arising from a multitude of potential causes and/or contributing factors (Washington & Haque, 2013). In such a chain, however, different causes may not necessarily originate from the same sources and they may also have varied contributions to crash occurrence. The nature of crash contributing factors is likely to reflect geometric characteristics of the road, spatial effects arising from features of the surrounding environment, and human behavioural factors. These three sources can influence crash occurrence via unique yet interrelated underlying avenues or risk processes. Thus, a primary consequence of postulating a single unique risk process is that the influence of each separated risk process on the final outcome (crash) is not differentiated and may be mistakenly associated to the incorrect sources of crash causal factors. Nevertheless, the state of the practice in road safety network management applies a Safety Performance Function (SPF) that represents the single risk process to explain crash variability across network sites and thus is incapable of linking various portions of total observed crashes caused by separate sources of causal factors (Washington & Haque, 2013).

The first attempts in the literature to understand crash causation process emerged by modelling crash risk based on several independent explanatory variables (Hauer, 1986). Crash Prediction Models (CPM) or Safety Performance Functions (SPFs) were developed to correlate crash contributing factors as explanatory variables with the total observed crash count to identify crash risk (Hauer, 1986, 1992, 1997; Joshua & Garber, 1990; Miaou, Hu, Wright, Rathi, & Davis, 1992; Miaou & Lum, 1993a, 1993b). However, this process was based on the fundamental assumption that a multitude of crash contributing factors operate in a single chain consisting of a series of events which ultimately lead to crash occurrence.

Accordingly, researchers tried to explore the relationship between crashes and variety of roadway geometric characteristics following a single crash generating process (Ardekani, Hauer, & Jamei, 1992; Lyon, Oh, Persaud, Washington, & Bared, 2003; Oh, Lyon, Washington, Persaud, & Bared, 2003; Vogt & Bared, 1998). Although it was recognised very early in the literature that crash contributing factors may originate from different sources such as climate conditions in addition to roadway geometric features (Hauer, 1986, 1997), a separation of such sources was largely ignored in crash risk modelling. Later, it was confirmed that spatial effects arising from features of the surrounding environment contribute to crash occurrence as well (Aguero-Valverde & Jovanis, 2006; Huang & Abdel-Aty, 2010; Mitra & Washington, 2012; Qin & Reyes, 2011; Yasmin & Eluru). However, SPFs still followed a single crash generating process. The evolution of crash risk modelling continued to progress mainly in refining the statistical shortcomings of the models. Such vast advances have been structured around the underlying assumption that crashes arise from a single unique risk process.

This study aims to elucidate the importance of differentiating among various underlying risk processes contributing to observed crash counts at any particular network location. It is postulated that potential crash contributing factors arise from three different underlying processes, including roadway geometric, spatial, and human behavioural factors. To demonstrate the principle of this theoretical and corresponding methodological approach, this study attempts to model two crash generating processes to initiate the multiple unique risk process models. In particular, this study explores engineering and unobserved spatial factors as two explicit sources of crash contributing factors, leaving the human behavioural factors as the next step of this research to further increase model complexities and improves models performances. A Bayesian Latent Class (BLC) analysis is used to investigate these two sources and to incorporate prior information about their contribution to crash occurrence. The methodology is applied to the state controlled roads in Queensland, Australia and the results are compared with the traditional Negative Binomial model.

Methodology

In order to explicitly assess the separated underlying risk processes, it is required to establish two separate SPFs correlating the predicted means of crash counts in each process (μ_1 and μ_2) with two different sets of covariates:

$$\mu_1 = {F_1}^{\alpha_1} e^{(\alpha_3 X_3 + \alpha_4 X_4 + \alpha_5 X_5 + \cdots)} e^{(\varepsilon_{i1})} \quad \text{Equation [1]}$$

$$\mu_2 = {F_1}^{\beta_1} e^{(\beta_3 Z_3 + \beta_4 Z_4 + \beta_5 Z_5 + \cdots)} e^{(\varepsilon_{i2})} \quad \text{Equation [2]}$$

where F_1 is the measure of exposure, X_i and Z_i are explanatory variables for each distinct risk process and α_i and β_i are unknown regression parameters. To incorporate randomness into the models, random terms (ε_{i1} and ε_{i2}) are added to SPFs. To account for unobserved heterogeneities, these random terms are allowed to vary across observations by assigning a Multivariate Normal distribution as follows:

$$\boldsymbol{\varepsilon_i} \sim MN(\boldsymbol{\xi}, \Sigma) \quad \text{where} \quad \boldsymbol{\varepsilon_i} = \begin{bmatrix} \varepsilon_{i1} \\ \varepsilon_{i2} \end{bmatrix}, \quad \boldsymbol{\xi} = \begin{bmatrix} \xi_1 \\ \xi_2 \end{bmatrix} \quad \text{and} \quad \Sigma = \begin{bmatrix} \sigma_{11} & \sigma_{12} \\ \sigma_{21} & \sigma_{22} \end{bmatrix}$$

where $\boldsymbol{\xi}$ is the vector of mean values and ξ_1 and ξ_2 are the mean values for random terms respectively. It should be mentioned that the above specification of multivariate distribution accounts for possible correlations between the two risk processes.

Each of the abovementioned predicated means accounts for a proportion (w_1 and w_2 respectively) of the total predicted mean of crash counts (μ):

$\mu_1 = w_1 \mu$

$\mu_2 = w_2 \mu$

$w_1 + w_2 = 1$

In other words, the total predicted mean of crash counts is a weighted sum of the two aforementioned means:

$$\mu = \frac{1}{2\,w1}\mu_1 + \frac{1}{2\,w2}\mu_2 \quad \text{Equation [3]}$$

where $\frac{1}{2\,w1}$ and $\frac{1}{2\,w2}$ are the predicted weights associated to each distinct risk process. Accordingly, the total observed crash counts (Y) which follows a Poisson distribution with the mean of μ is a weighted sum of two latent (underlying) crash counts (Y_1 and Y_2); each one representing a proportion (W_1 and W_2 respectively) of the total observed crash counts:

$Y_1 = W_1 Y$

$Y_2 = W_2 Y$

$W_1 + W_2 = 1$

Or equivalently:

$$Y = \frac{1}{2\,W1}Y_1 + \frac{1}{2\,W2}Y_2$$ Equation [4]

where $\frac{1}{2\,W1}$ and $\frac{1}{2\,W2}$ are the observed weights associated with each distinct risk process. Indeed, the proposed methodology utilises the BLC analysis and prior knowledge in order to determine w_i as an estimate of W_i which illustrates the contribution of each risk process to the total observed crash counts. Having been assigned a distribution with known parameters (known from the prior knowledge), these weights are allowed to vary across observations. The proposed model is calibrated in a Bayesian framework where the posterior is equal to the product of likelihood: P(Y| μ) and prior: π(μ). Markov Chain Monte Carlo (MCMC) simulation is used to estimate the entire unknown parameters including w_i, α_i, β_i, ς_i and σ_{ij} and to make inferences about the posterior.

Finally, the Bayesian Information Criterion (BIC) is used to compare the performance of models:

BIC = -2 Log Likelihood + p Log (n) Equation [5]

where *p* and *n* are the number of estimated parameters and the number of observations respectively and the model with a lower DIC and BIC values outperforms the other models.

Data

The methodology is applied to the network of state controlled roads in Queensland, Australia consisting of 4,913 roadway segments and approximately 33,510 kilometres in length. Five years of crash data (2010 to 2014) with a total count of 18,484 crashes associated to the network were analysed. All crash severities were included (fatal, hospitalisation, medical treatment, minor injury and Property Damage Only).

Roadway geometrical characteristics were collected from the Queensland Transport and Main Roads Department in GIS formats. The database included segments length, number of lanes, Average Annual Daily Traffic (AADT), percentage of Heavy Vehicle (HV) traffic, Level Of Service (LOS), segments terrain (horizontal and vertical alignment), pavement seal conditions, speed limit, pavement rutting, roughness, longitudinal and alligator cracking conditions. The number of lanes did not vary significantly across observations and thus was not included in the model. The Average Annual Daily Traffic (AADT) of road segments was employed as the exposure variable. LOS is defined as a qualitative measure of traffic service in the road which scales from A to F (Garber & Hoel, 2014) as in the following:

LOS A: Highest quality of service; motor vehicles drive at their desired speed
LOS B: Lower quality of service; the passing demand and passing capacity are almost equal
LOS C: Formation of platoons and platoon size; passing opportunities are severely decreased.
LOS D: Unstable flow and incomplete passing manoeuvres
LOS E: Impossible passing; longer and more frequent platoons; unstable operating conditions
LOS F: Full congestion; demand exceeding capacity.

Moreover, it was found that pavement rutting, roughness, longitudinal and alligator cracking conditions were all highly correlated and so to avoid multicollinearity, only pavement rutting conditions were included in the model. Pavement rutting is defined as permanent deformations of the pavement in the wheel paths. The maximum allowable rutting is 12mm and thus segments rutting was defined as between 0 (the smoothest pavement surface) and 12mm (the roughest surface). Dummy values were assigned to the speed limit, general terrain and pavement seal conditions of road segments to create associated categorical variables. Speed limit was categorised into three groups including low speed limit (Speed Limit<50Km/hr), medium speed limit (50 <Speed Limit<100Km/hr) and high speed limit (Speed Limit>100Km/hr). Terrain condition includes two categories: level and mountainous/rolling. Surface seal condition also includes two categories: sealed and unsealed.

Many studies have emphasised the influence of spatial features of the transport network, such as precipitation, number of rainy days, number of snowy days, presence of college or university within a certain distance of road segments, on crash occurrence (Aguero-Valverde & Jovanis, 2006; Mitra & Washington, 2012). To investigate the effects of such factors, climate data were collected from Australian Bureau of Meteorology for the associated network. Climatic factors included average yearly rainfall (over 5mm), average rainy days per year, average daily solar exposure as well as average sunshine hours (to capture glare effects of sunshine on drivers), average monthly wind speed, and average thunder days per year. To better capture the effects of rain and solar conditions and facilitate the interpretation of rainfall and days of rain as well as solar exposure and sunshine hours, two new variables were established to capture the combined effects of these variables. The former was achieved via dividing rainfall by number of rainy days per year and the latter by dividing solar exposure by number of sunshine hours per day, and these new variables were named as 'rain conditions' and 'solar conditions', respectively.

To incorporate the effects of adjacent land use patterns, the geographic locations of schools and population centres were collected from the Queensland Spatial Catalogue in GIS formats. As there are many vulnerable road users (pedestrians) in the vicinity of such centres, their proximity to road segments may increase the risk of crash occurrence. Moreover, the intensity of bridges and culverts (number of bridges and culverts per kilometre) were also derived from the geometrical database. Such factors can influence the concentration and cautiousness of drivers which can be interpreted as unobserved spatial effects of the surrounding environment. Eventually, engineering and spatial data were merged using a GIS platform based on spatial coordinates of roadway segments. Table 1 presents descriptive statistics of the study variables.

Table 1. Descriptive Information of study variables

Variable	Minimum	Maximum	Mean	Standard Deviation
Crash	0	150	4	8
Length (Km)	0	63.4	6.8	7.7
AADT (Vehicles/Day)	0	72405	7594	11753
Percent of HV Traffic	1	92	16.7	10.9
Rutting	0	11.2	3.7	1.6
Rainfall (mm)	0	8000	1276.4	976.5
Number of Rainy Days per Year	0	75	36	11
Solar Exposure (MJ/m^2)	0	24	20.8	3.2
Sunshine Hours per Day	0	10	8.3	0.5
Number of Thunder Days per Year	0	80	25	6
Wind Speed (Km/hr)	0	26	11.6	5.4
Intensity of Major Culverts per Kilometre	0	76.2	0.4	3.6
Intensity of Minor Culverts per Kilometre	0	571.4	3.6	21.1
Intensity of Bridges per 10 Kilometres	0	9.5	0.1	0.4
Intensity of Educational Centres per 10 Kilometres	0	16	0	0.35
Proximity to population centres (Km)	0	1456.7	54	146.5
Categorical Variables	**Observation Frequency**		**Sample Share**	
High Speed Limit (>100 Km/hr)	2442		50%	
Medium Speed Limit (>50 and <100 Km/hr)	2386		48%	
Low Speed Limit (<50 Km/hr)	85		2%	
Terrain[1]	866		18%	
Pavement Seal Conditions[2]	4670		95%	
LOS[3]	3370		68%	

[1]0 (if Level), 1(if rolling and/or mountainous)
[2]0 (if un-sealed), 1 (if sealed)
[3]0 (if A, B, C or D), 1(if E or F)

Results and Discussion

Negative Binomial (NB) regression model is the widely accepted safety performance function to establish the relationship between traffic crashes and contributing factors (Poch & Mannering, 1996). Thus, estimating a traditional NB model with a single risk process was the first task in this study. Table 2 presents the results of NB model estimated in Bayesian framework. According to Table 2, the 90% credible intervals for the dispersion parameter (Φ) of NB model does not include zero. This indicates the presence of significant over-dispersion in crash data and thus it is necessary to utilise the NB model to account for such an over-dispersion. Thirteen variables out of all factors used in the study were significant in the NB model with 90% certainty. Some of these variables had positive effects, while others had negative effects on the total crash count. The AADT, length and terrain configuration of road segments had positive coefficients indicating that greater volume of traffic, longer road segments and rolling and/or mountainous terrain results in higher number of crashes. Furthermore, positive coefficients for low and medium speed limits along road segments intuitively indicated that compared with motorways, arterial roads are more associated with traffic crashes. The percentage of heavy vehicles, rain conditions, solar conditions, average number of thunder days per year, wind speed, intensity of bridges and schools had negative coefficients, indicating that these variables have decreasing effects on the total crash count. In adverse weather conditions, drivers may adapt and drive more cautiously, which might have resulted in negative association with total crashes. Pavement seal conditions and LOS also had negative coefficients, indicating that changing from unsealed to sealed and from congested to free flow conditions result in less crashes.

Table 2. Regression results of the Traditional NB model with a single risk process

Variables	Mean	Std. Deviation	Bayesian Credible Interval (BCI) 10% Value	90% Value
Constant	-9.664	0.509	-10.290	-9.122
AADT	0.755	0.026	0.722	0.786
Length	0.665	0.025	0.634	0.694
Percent of HV	-0.030	0.002	-0.032	-0.027
Terrain	0.083	0.039	0.033	0.133
Pavement Seal	-0.289	0.098	-0.430	-0.178
Low Speed Limit	0.845	0.144	0.661	1.031
Medium Speed Limit	0.732	0.035	0.687	0.777
LOS	-0.290	0.043	-0.346	-0.235
Rain Conditions	-0.123	0.095	-0.247	-0.002
Solar Conditions	-0.068	0.034	-0.115	-0.025
Thunder Days	-0.371	0.193	-0.609	-0.107
Wind Speed	-0.234	0.071	-0.326	-0.140
Intensity of Bridges	-2.424	0.667	-3.298	-1.566
Intensity of Schools	-1.027	0.448	-1.603	-0.454
Φ	1.961	0.079	1.860	2.064
Number of Observations (Sample Size)	4913			
Number of Parameters	16			
Log Likelihood	-9145			
Bayesian Information Criteria (BIC)	18426			

The next step was to apply the multiple generating process SPFs on the data. Crash contributing factors were categorised into two sources: engineering factors and spatial factors. Engineering factors included segments length, percentage of heavy vehicles, general terrain, pavement surface conditions, speed limit, LOS and rutting conditions of road segments. Spatial factors included rain conditions, solar conditions, average number of thunder days per year, average annual wind speed, number of major and minor culverts as well as number of bridges along the road segments, intensity of educational centres, and the proximity of road segments to population centres. Since exposure factors play a vital role in crash occurrence models, the exposure variable and its coefficients were set to be the same in both risk processes following the formulation in eq. 6. This implies that there exists a base crash count associated with exposure, irrespective of any other crash contributing factors. As a result, for the multiple risk process model eq. 6 is simplified to the following:

$$\mu = F^{\alpha 1} \times (\frac{1}{2\ \omega_1}\mu_1 + \frac{1}{2\ \omega_2}\mu_2) \qquad \text{Equation [6]}$$

where:

$$\mu_1 = e^{(\alpha_3 X_3 + \alpha_4 X_4 + \alpha_5 X_5 + \cdots)} e^{(\varepsilon_{i1})}$$

$$\mu_2 = e^{(\beta_3 Z_3 + \beta_4 Z_4 + \beta_5 Z_5 + \cdots)} e^{(\varepsilon_{i2})}$$

F is the exposure variable and the remaining notations are the same as previously stated. According to the literature (Washington & Haque, 2013), unobserved spatial factors account for approximately 5 to 10 percent of all crashes and thus a uniform distribution ranging from 0.05 to 0.15 was used in this study as a prior distribution for the proportion of spatial risk process. Although the MCMC simulation resulted in Markov chains which were stabilised and converged for most of the regression parameters, the ultimate convergence of the model needs to be improved in future efforts. The regression results for the multiple risk process model are presented in Table 3.

A comparison of the two tables shows that the traditional NB regression analysis with a single risk process results in a model with Log likelihood of -9145 while the Log likelihood of the multiple risk process model is -7335, demonstrating 20% improvement compared to the traditional NB model. It should be noted, however, that separating two generating processes leads to an increase in the number of parameters to be estimated. While the number of observations in the three models is 4913, the NB and the multiple risk process models have 16 and 20 parameters to be estimated respectively. According to Tables 2 and 3, the BIC value of the multiple risk process model (14840) is smaller than the BIC value of the traditional NB model (18426) which clearly shows the dominance of the former model in goodness of fit.

The prominent result of this study, however, is that according to Table 3, crash contributing factors originate from two distinct sources associated with two latent risk processes including engineering and spatial factors. The mean proportions of these two sources across observations (w_i) are 90% and 10% respectively. The variance and confidence intervals of such weights show that the contribution of such sources is significant with 90% certainty.

The coefficients of all significant variables excluding the average number of thunder days per year had the same sign in both models. However, the NB model resulted in a negative coefficient for the average number of thunder days while separating the two risk processes caused the coefficient sign to become positive. This result could be considered more intuitive in which increasing the number of thunder days per year results in an increased crash counts at road segments.

Table 3. Regression results of the multiple risk process model

	Mean	Std. Deviation	Bayesian Credible Interval (BCI) 10% Value	90% Value
Exposure Factor				
AADT	0.685	0.021	0.663	0.713
Engineering Factors				
Constant	-9.099	0.270	-9.393	-8.810
Length	0.664	0.010	0.652	0.677
Percent of HV	-0.037	0.002	-0.040	-0.034
Terrain	0.054	0.038	0.005	0.103
Pavement Seal	-0.332	0.043	-0.391	-0.278
Low Speed Limit	0.675	0.148	0.486	0.862
Medium Speed Limit	0.696	0.036	0.651	0.744
LOS	-0.204	0.045	-0.261	-0.148
Spatial Factors				
Constant	-11.590	1.512	-13.780	-9.970
Solar Conditions	-1.540	2.107	-1.809	-0.817
Thunder Days	5.648	3.341	2.261	10.380
Wind Speed	-9.324	4.210	-14.850	-5.127
Random Terms				
ε_1	0.059	0.053	0.007	0.137
ε_2	0.761	0.526	0.142	1.521
σ_{11}	4.182	1.713	2.551	7.015
σ_{22}	0.326	0.127	0.189	0.490
$\sigma_{12} = \sigma_{21}$	-0.767	0.410	-1.383	-0.321
Average Risk Process Weighs				
w_1	0.900	0.000	0.900	0.901
w_2	0.100	0.000	0.099	0.101
Number of Observations (Sample Size)	4913			
Number of Parameters	20			
Log Likelihood	-7335			
Bayesian Information Criteria (BIC)	14840			

A further assessment of the mean values for the regression coefficients indicated that while significant engineering variables had the same increasing/decreasing effect in both models, their coefficients changed very slightly in magnitude from one model to another. However, separating the two risk processes caused a dramatic change in the coefficient magnitudes of solar conditions (from -0.068 to -1.540), average number of thunder days per year (from -0.371 to 5.648) and wind speed (from -0.234 to -9.324). Bearing in mind that this dramatic change occurred in the proposed model where six other spatial variables became insignificant, it can be inferred that separating the two risk processes caused the three previously mentioned variables to absorb the majority of spatial effects. The BCI values for ε_1, ε_2, σ_{11} and σ_{22} indicated that the random terms and their variance were significant with 90% certainty for each distinct risk process. It is noteworthy that the BCI values for σ_{12} and σ_{21} did not include zero, indicating that there is a correlation between the two risk processes.

This finding could be indicative of the fact that the two risk processes were distinct and yet interrelated.

Conclusions

This study aimed to demonstrate the principle of a multiple risk process mechanism for crash causation and its corresponding methodological approach. The objective was achieved by differentiating between two distinct crash generating processes including engineering and unobserved spatial factors. A traditional NB count model was initially estimated for the means of comparison with the new proposed multiple risk process model.

It was concluded that the crash data is over-dispersed and thus the traditional NB model is appropriate to capture the over-dispersion. A comparison of BIC values for the NB and the multiple risk process models clearly showed the dominance of the latter in terms of goodness of fit. Further, a comparison of significant variables indicated that while many spatial factors were not significant when separately modelled, solar conditions, average number of thunder days and wind speed were significant in the spatial risk process. Moreover, significant changes occurred in coefficient magnitudes of such variables when spatial factors are separately modelled. This clearly shows that these three spatial factors play influential roles among other spatial variables in the spatial risk process. Furthermore, the decreasing effect of average number of thunder days per year on total crash counts changed to an increasing effect after separating the two risk processes, consistent with expectations.

In summary, it can be seen that the performance of SPFs in goodness of fit is significantly improved by separating the two distinct processes. Further, the multiple risk process SPF methodology illuminates the true significance and influence of crash contributing factors on crash occurrence. Future research should include all three crash generating processes, including engineering factors, spatial factors, and human behavioural influence, into the SPFs and demonstrate their implications for black spot identifications.

Limitations

The scope of this research was limited to investigating the influence of postulating two risk processes including engineering and spatial factors on the crash occurrence over the state controlled road network in Queensland. Human behavioural data such as gender, age, and possession of driving licence is directly associated with the third risk generating process (behavioural factors) which is out of the current scope of this research. Although a comprehensive assessment of crash causation process should include all three distinct sources of crash contributing factors, i.e. roadway geometric, spatial, and human behavioural factors, this study aimed to demonstrate the principle of postulating multiple risk processes for crash causation and corresponding methodological approach. Future research efforts should expand the proposed model and include all three underlying processes of crash occurrence. Moreover, vehicle characteristics may be considered as another source of crash contributing factors. However, mitigating such factors is beyond the scope of road agencies and thus it was not dealt with in this context.

The focus of the study was on the development of a theoretical model and thus a representative dataset was collected for the state controlled roads in Queensland to validate the proposed model with real-world data. Although the network only consisted of roadway segments (excluding intersections), the distinction between rural and urban roads was not available in collected data. However, geometric characteristics of the segments (e.g. length and AADT) partially accounted for the principal differences between rural and non-rural segments. Future research should apply the proposed model on a more extensive dataset that consists of road segments in urban and rural road environment separately and includes a wide range of roadway geometric and traffic control characteristics.

Furthermore, it should be noted that the analysis is still in its initial phase and requires more complex modelling techniques for better MCMC convergence, different sets of distribution assumption for weights of latent risk processes, and exploration of other possibilities like a random parameter (RP) model. RP models may potentially improve the analysis due to the fact that observations are broadly distributed over the Queensland state and thus assuming all parameters as fixed for the entire population may influence the results.

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Socio-cultural influences on vehicle defects in the Omani heavy vehicle industry

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Abstract

With recent economic growth in Oman there is increased use of heavy vehicles, presenting an increase in heavy vehicle crashes, associated fatalities and injuries. Vehicle defects cause a significant number of heavy vehicle crashes in Oman and increase the likelihood of fatalities. The aim of this study is to explore factors contributing to driving with vehicle defects in the Omani heavy vehicle industry. A series of qualitative participants observations were conducted in Oman with 49 drivers. These observations also involved discussion and interviews with drivers. The observations occurred at two road-side locations where heavy vehicle drivers gather for eating, resting, vehicle check-up, etc. Data collection was conducted over a three week period. The data was analysed using thematic analysis. A broad number of factors were identified as contributing to the driving of vehicles with defects. Participants indicated that tyres and vehicle mechanical faults were a common issue in the heavy vehicle industry. Participants regularly reported that their companies use cheap, poor quality standards parts and conducted minimal maintenance. Drivers also indicated that they felt powerless to resist company pressure to drive vehicles with known faults. In addition, drivers reported that traffic police were generally in effective and lacked skill to appropriately conduct roadside inspection on trucks. Further, participants stated that it was possible for companies to avoid being fined during annual or roadside vehicle inspections if members of the company knew the traffic police officer conducting the inspection. Moreover, fines issued by police are generally directed to the individual driver rather than being applied to the company, thus providing no incentive for companies to address vehicle faults. The implications of the findings are discussed.

Keywords: Road traffic crashes; vehicle defects; Bronfenbrenner Ecological Development Model; Deterrence Theory; Safety; Oman.

Introduction

The United Nations General Assembly (2003) identified five main areas for road safety improvement; these are the road infrastructure, road users' behaviours, emergency services, leading agency and vehicle characteristics. Rechnitzer (2002) stated that to improve road safety, controls on vehicle safety factors such as break inspection and maintenance standards must be addressed to reduce the prevalence of vehicle defects and number of associated crashes. In addition, Blower and Woodrooffe (2012) reported that vehicle defects and inappropriate maintenance are a common cause of crashes. The issue of vehicle defects remains a common problem within heavy vehicle transport industries. Rechnitzer, Haworth, & Kowadlo, (2000) reported that even though vehicle defects contributed to approximately 6% of crashes in Victoria, Australia, an even greater number of vehicles on roads could be classified as un-roadworthy despite annual technical inspections. Moreover, Mohan and Bawa (1985) found that, buses and trucks accounted for 65% of brake failure caused road traffic crashes in Delhi. Cuerden, Edwards and Pittman, (2011) reported that the most common vehicle faults that contributed to crash occurrence and severity of injury in UK during (2009) were found to be illegal tyres and break failures.

In the Omani context, Al Bulushi, Edwards, Davey, Armstrong, et al. (2015) examined heavy vehicle crash data that was obtained from the Royal Oman Police (ROP) for the period from 2009-2011. They reported that vehicle defects were the primary cause of 10% of fatal crashes and that crashes caused by vehicle defects were three times more likely to result in a fatality. The ROP reported that 243 crashes (light and heavy vehicles) occurred because of vehicle defects (mostly tyre defects) in 2013, compared to 178 in 2009. These vehicle defect-related crashes in 2013 led to at least 61 deaths and 243 injuries (ROP, 2013). The number of crashes due to vehicle defects are increasing in Oman, and further investigation is required to understand and examine the magnitude and characteristics of the problem, particularly in the heavy vehicle industry.

Heavy vehicle defects and their contribution to road traffic crashes and fatalities may also be influenced by factors which are not controlled by the driver. Company factors, customers, government departments, and road and working environments can all influence heavy vehicle safety (Edwards, Davey, & Armstrong, 2014). When exploring the factors which influence vehicle defects in Oman, it is important to explore the cultural context of heavy vehicle operations. In the Oman context, governments polices and legislations, trucking industry operations, police enforcement, road environment and heavy vehicle driver characteristics should all be considered. To explore these factors and how they related vehicle defects within the industry, the current research applied the ecological development model. This model originated from research into human development (Bronfenbrenner, 1977). In this model there are four systems (micro, meso, exo and macro) which help formulate behaviours. These four systems and their relevance to the research are briefly discussed below. This framework has been used in multiple different research settings to understand the variety of influences on health and safety outcomes.

For the purpose of this study, the micro-system referred to the immediate physical environment including heavy vehicle gathering and rest areas, and heavy vehicle characteristics. The meso-system included the environment surrounding the microsystem (road infrastructure and surrounding facilities). The exo-system included the heavy vehicle industry workplace environment, government legislation and policies as well as traffic law and enforcement (in this paper, to provide better clarity, this system is further divided into two sub-systems representing the organisation and policing). The macro-system here was used to understand the legal and political context, general overarching culture and international influences on heavy vehicle safety. These headings were used in the results and discussion below.

In the absence of sufficient research within Oman, there is limited current knowledge of factors which influence heavy vehicle safety. The aim of this study is to provide greater knowledge of the key influences on heavy vehicle defects and to explore how these influences lead to safety outcomes and safety-related behaviour within the trucking industry in Oman.

Method

A series of observations were conducted of heavy vehicles and their drivers within Oman as part of a larger study examining safety broadly. During these observations the researcher travelled to two major roadside locations where heavy vehicle drivers gather, took notes on the level of maintenance of heavy vehicles that were parked at these locations (e.g. tyre tread, and visible aspects of the vehicle), observed the interactions between drivers and conducted informal interviews with heavy vehicle drivers at these sites. Additionally, a number of ride along observations were conducted, where the researcher joined drivers on their journey to deliver goods, taking notes of observed interactions and ongoing informal discussions with the drivers.

While no participant information was provided to the drivers of vehicles that were not present when their vehicle was any time a driver was approached for discussion, or questioned the researcher as to why they were present, the researcher introduced themselves and the purpose of the study as well as relevant participant information. This study received ethical clearance from the Queensland University of Technology Human Research Ethics Committee.

Prior to undertaking the study the researcher undertook training at a police inspection depot for heavy vehicles, observed a full day of inspections and was instructed by the officers as to what to look for whilst casually observing a heavy vehicle. Almost all drivers who were approached agreed to be involved to varying depth of conversation and levels of vehicle observations. At the end of each day notes and discussion were transcribed in Arabic language and then translated into English for reporting. The transcripts were entered into NVivo 10 for analyses. Thematic analysis was conducted, guided by the ecological development model. That is, data c=was coded according to levels of the model, and subthemes were identified within. For the purpose of reporting, the participants quotes are identified in the result section as ‘Obs##’. A total of forty nine participants were involved in interviews from which quotes were drawn. Not all participants discussed vehicle defects, however, of those that did there was a high level of congruence in themes discussed.

Results and Discussion

The observations identified two common areas where vehicle defects occur. These were bald or re-treaded tyres and general mechanical faults, and for the purpose of this research are considered to form the microsystem (as the final behaviour that influences safety is the decision to drive with a vehicle with these defects). Each of these issues was influenced by the other three systems. Each of these is discussed below within the relevant ecological systems levels.

The Micro-system

Poor quality standards of re-treaded tyres were almost universally present in the heavy vehicle industry regardless of the company.

> *Whether it is a small company or a large one, every single truck would have 3-7 defected tyres* (Obs6).

In addition, many participants reported the frequent occurrence of hydraulic brake system failure, drum wheel cracking and breakage while driving, as well as failures in tie rods, steering rods and air balloon valves. Participants stated that these defects were associated with crash involvement in many instances. In many cases, participants stated the main cause of these faults and breakages to be the usage of substandard spare parts. Substandard or low quality spare parts were frequently used to replace genuine manufacturer parts as they were significantly cheaper. Within Oman, this practice is popularly referred to a “duplicate parts”.

> *In general, the fundamental problems that we face are the failure of hydraulic braking system and broken drum wheel. This can cause a serious crash, because we lose the main means of truck control. Some of the reasons for this were due to the use of duplicate (poor quality standard) or commercial spare parts* (Obs8).

The majority of the observed heavy vehicles in both study sites were fitted with multiple bald, cracked or poor quality re-treaded tyres. The risk in using these poor quality tyres is significantly increased when one observes the distance between two poor quality tyres paired on the same axle. When combined with commonly overloaded vehicles the gap between tyres becomes very narrow. This becomes critical when the gap closes and generates heat resulting in tyre explosion.

With regard to general mechanical faults, the most common heavy vehicle mechanical faults that were reported were associated with brake failure. In the event of a brake malfunction, the inability to control the truck significantly increases crash likelihood.

Overall, it was clear that poor levels of vehicle maintenance was common. Further, drivers appear to be willing to drive these vehicles. As such, it is important to understand the factors which lead to the occurrence of these defects, and encourage drivers to operate these vehicles.

The Meso-system

In general, road infrastructure can play a significance role in safety and this is particularly the case within the Omani heavy vehicle industry. In Oman, the police traffic law requires truck drivers' to drive on the far right lane of the roads. The heavy usage of this lane by trucks, especially when they were overloaded, results in rapid destruction the road surface. As a result, the road surface causes continuous vibrations to the vehicle and drivers while on the road. These vibrations can structurally affect the mechanics of the truck.

> *The truck lane surface that most of the trucks must drive on (far right lane) in some location were worn out due to the heavy usage of this lane by trucks. This lane surface causes vibrations of the truck body leading to eclectic failure to lights and hydraulic break wire connections disruption* (Obs23).

This issue can be argued to indicate failures at a transport authority level. There appears to be an absence of road monitoring, supervision and evaluation programs within the transportation authorities. Further, there is an absence of measures to monitor and enforce truck weights. These issues need to be addressed to reduce the problem of vehicle defects within the Omani heavy vehicle industry.

The Exo-System

There were two main influences that were categorised as part of the exosystem. These were transport companies and road safety policing. For clarity, the exo-system has been separated into two separate systems reflecting these two influences.

Exo-police system

Road policing forms one of the strongest influences on road safety internationally. The primary means by which police in Oman can influence vehicle defects in the heavy vehicle industry is through heavy vehicle technical inspections. The responsible authority for the technical inspection within Oman is the ROP. The ROP traffic law requires every heavy vehicle registered in Oman to undergo annual technical inspection, and police also conduct occasional road side inspections. It became evident very early in the research that legislations, enforcement and monitoring system with regards to technical inspection needs to be strengthened. However, to maintain high quality of vehicle inspection and meeting international standards, participants acknowledged that in companies such as the Petroleum Development of Oman (PDO) and Occidental Oman (Oxy) conduct their own vehicle maintenance inspections.

> *Like you have the PDO and Oxy, they have strong inspection guidelines and will not allow passing any vehicle if not fulfilling all requirements without any mediation. While in the police, social influence can play a big role in passing some of trucks where defects were highlighted in breaching some of the requirements (what I mean by social influence is that, the company owner knows some police officers, they may be relatives or friends)* (Obs48).

Many of the participants reported that traffic police lack sufficient knowledge with regards to on-road heavy vehicle inspections. They reported that police commonly issue tickets for tyres defect and lights, yet fail to inspect for, or detect, other defects such as hydraulic brake system failure and drum wheel cracking. This indicates a need to improve traffic police knowledge and training with respect to on road heavy vehicle inspection.

> *At the time of being stopped for inspection, they only practice the normal procedures of checking such as tyres, lights, flash (yellow lights) at the forefront and the rear of the truck* (Obs10).

Driving a truck with bald tyres and known mechanical faults is an offence by traffic law. While drivers were accepting of this, they criticised the current police ticketing in terms of how, and to whom, tickets were issued. Traffic police generally issue vehicle and maintenance related tickets to the driver's licence. Once tickets are issued to a driver's license, the driver is responsible to pay the fine. However, under Omani law the ticket can also be issued to the registered owner of the vehicle. To our knowledge, this approach is rarely if ever used, even though under the law vehicle maintenance is considered the responsibility of the owning company. Thus there is no punitive incentive for transport companies to improve vehicle maintenance. While driver's would ideally refuse to drive vehicles with defects, they do not own the vehicle and thus cannot ensure proper maintenance. As such, it would be beneficial for police to direct their efforts toward fining vehicle owners, rather than drivers of heavy vehicles.

> *In some cases, if you have been stopped by the police for tyre offences, the ticket issued on the driver license and supposed to be ticketed on the company or the owner of the truck* (Obs9)

According to deterrence theory, individuals are deterred from a behaviour as a function of their perception of the severity, swiftness and certainty of punishment (Elvik & Christensen, 2007; Watson & Freeman, 2007). The interviews and field observations identified a range of deterrence weaknesses in the current police sanctions for vehicle defects. To use an example, when a driver is ticketed for tyre defects they are fined an equivalent to approximately AU $115. This fine is to be payed at the end of the year, or at the vehicle annual technical inspection. More importantly the vehicle is still allowed to operate with the defective or damage part. When this is combined with the relatively low likelihood of detection, there is a lack of certainty, severity or swiftness. While annual inspections can result in seized vehicles, drivers frequently reported that when a heavy vehicle does not pass an annual inspection, punishments can be completely avoided "if they knew someone in the police", resulting in a passed inspection. Whilst issues related to knowing police officers are likely cultural issues that may be difficult to overcome, the findings overall highlight the need to review the current police operations and practices related to vehicle defect offences.

> *If the police seize the vehicle for these types of offences, the factory managers will run to rid the truck. In addition, the fine is not enough, that is why you see the same offence repeated so many times, but "if you give them a strong nip they will not repeat it"* (Obs43).

Exo-company system

Within Oman legislation, the majority of companies are required by law to have a health and safety policy statement, and larger companies must also employ a health and safety officer (Ministry of Manpower, 2008). However, it does not automatically follow that companies apply and adhere to their own health and safety policies. The interviews and field observations identified two broad levels of health and safety standards within the industry. Some companies facilitated a high standard of workplace health and safety, while other companies paid little attention to workplace safety.

There were a small number of companies that appeared to be highly focused on safety. These companies were exclusively large Omani oil and gas organisations, such as the Petroleum

Development Oman, which follow international standards of best practice. However, the majority of companies that drivers in the observations were employed by had relatively low operational levels of workplace health and safety. With respect to these organisations, if drivers did report that their company had workplace safety polices, these policies were almost never followed or supported by management. As such, drivers highlighted that health and safety policy requirements were ineffective in promoting safe practices among companies employees. In addition, participants stated that these companies produce routine reports to the Ministry of Manpower inspectors that enforce company compliance, yet that these reports were completed solely to appease inspectors and did not reflect actual health and safety performance.

> *When you talk about safety, believe me most of the companies that have a fleet of heavy vehicles do not have the true meaning of safety or road safety, safety of trucks and their drivers. With the exception of oil and gas companies such as PDO and National Gas Company, other than these companies, they claim to be having safety system in their companies but that is only to show to government organisation that they have a safety system for their employees, but in fact this is not true* (Obs30).

Researchers around the world highlight the importance of the organisation safety culture in formulating employee behaviours (Guldenmund, 2010). With specific regard to vehicle defects, these less safety-focussed companies would ignore driver reports about mechanical faults. Additionally, participants emphasised the pressure to work in unsafe conditions from company management. Most drivers reported that they were forced to drive their trucks with known faults or defects, or face punishment. For expatriate drivers, this can even include a loss of work visa and requirement to leave the country.

> *There is air leakage from rear brake pipe, I have told the company in-charges about the problem but no action taken yet, I am a driver and I follow orders from my supervisors to drive the truck with this fault* (Obs7).

> *These tyres pose a major threat in crash involvement and public safety, we have no any hand to change the company decision in what type of tyres to be used, we are drivers and we accept what they offer* (Obs22).

In Oman, there is a need for government intervention targeting transport organisations. Without sufficient motivation to ensure companies promote safe behaviour, it is unlikely that heavy vehicle safety can be significantly improved.

Macro-System

As was noted in the previous section, a small selection of companies had high standards of workplace health and safety. These companies included oil, gas and chemical companies. These companies were involved in maintaining a high standard of safety and safety culture in all aspects of their activities whether at the depot or on the road. One of the key reasons for these activities was that these companies engaged in trading with the international market, in which the implementation of a high standard of safety is a general requirement. Hence, continuation and maintenance of this safety standard in Oman or any place where these companies located is crucial for these companies. While it is difficult to see how this could be used to improve safety in companies that have no international market, it is important to recognise that this does indicate the power of customers to influence transport companies. While drivers did not highlight the role of customers, it is evident that customers can have an influence on health and safety practices, if they have a reason to do so.

> *For the presence of regulations and documents concerned with road safety and safety in the facility, only large companies have such regulations such as PDO. These companies have*

their own company field inspectors to monitor the drivers and issue tickets for the offenders and apply the company's penalties on them (Obs4).

Conclusions

This study aimed to explore the key influences on heavy vehicle safety defects in Oman. Two major areas of vehicle defects were identified in this study, driving a truck with bald or poor quality re-treaded tyres and general mechanical faults. There were a number of influences on driving with these defects. Through using the ecological systems model, these influences were separated into a number of systems. It should be noted that each of these systems may have effects on one another. Within the present study, such interactions were not found to have a major effect on driving with vehicle defects, nonetheless it should be noted that these systems do not exist in isolation.

The mechanical faults identified in this study included hydraulic break failure, steering and tie rods breakdown and balloon air valve failure. While there were examples of strong workplace health and safety operations and environments, the majority of employing companies appeared not to value workplace health and safety policies and held little fear of government inspectors. Due to the many influences on the industry, drivers were found to be powerless and forced to engage in driving unsafe vehicles. Many drivers felt unable to refuse their company managers and supervisor’s requests or directives. This could be further explained by the fact that many drivers are expatriates and the company has the ability to cancel their work visa. When this issue is combined with weaknesses in enforcement as well as the effects of road infrastructure on the vehicles, it highlights the need for system wide initiatives. It is evident that the problem of vehicle defects cannot be addressed with a sole emphasis on attempting to change driver behaviour.

Importantly this research highlighted the overall importance of the employing companies influence on operational road safety. In comparison the operational focus of introduction activities appears to be on the driver. However within this unique Oman context the singular focus on the driver as a point of intervention will yield little overall improvement in road safety outcomes. In fact it will only continue to reinforce a status quo where industry continues in exploiting cultural and legislative weaknesses to their financial benefit for the sake of drivers and the communities’ safety.

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Policing of road safety in Oman: Perceptions and beliefs of traffic police officers

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Abstract

With increasing motorisation, road safety has become a major concern within Oman. Internationally, traffic policing plays a major role in improving road safety. Within Oman, the Royal Oman Police's (ROP) Directorate General of Traffic is responsible for policing traffic laws. Many common enforcement approaches originate from culturally different jurisdictions. The ROP is a relatively young policing force and may have different operational practices. Prior to applying practices from other jurisdictions it is important to understand the beliefs and expectations within the Directorate General of Traffic. Further, there is a need for individuals to understand their role and what is expected of them. Therefore, it is important to explore the agreement between levels of the ROP to determine how strategies and expectations transfer within the organisation. Interviews were conducted with 19 police officers from various levels of the ROP. A number of themes and findings emerged. Individuals at the upper level of the traffic police had a clear knowledge of the role of the ROP, believed that traffic police know what is expected of them, are well trained in their role and can have a very positive influence on road safety. These beliefs were less certain lower within the organisations with traffic officers having little knowledge of the role of the ROP or what was expected of them, felt undertrained, and believed their peers have little positive impact on road safety. There is a need to address barriers within the ROP in order to positively impact road safety.

Introduction

The World Health Organization (WHO, 2013) reported that road traffic injuries are the eighth leading cause of death globally, and the leading cause of death for young people aged 15–29. WHO (2012) also reported that more than a million people die each year on the world's roads, and the cost of overcoming the results of these crashes is estimated in the billions of dollars. Although, Gulf Cooperation Council (GCC) Countries (e.g. Oman, United Arab Emirates, Saudi Arabia, Qatar, Kuwait& Bahrain) are rapidly developing new high standards of roads, they still have among the worst rates of road fatalities.

Oman has one of highest rates of road fatalities and injuries in the world. In November 2012, the World Health Organization ranked Oman third globally in terms of road crash fatalities, with 31.1 fatalities per 100.000 people. Over the 10 years to the end of 2013, the annual number of road fatalities in Oman increased from 578 to 913 (Royal Oman Police (ROP), 2013). By comparison, in the 12 months to the end of March 2012, Australia (with a population almost five times higher than Oman) reported 1310 road fatalities (Department of Infrastructure and Regional Development, 2012).

Within Oman, the ROP is tasked with managing road safety and undertaking traffic law enforcement. The legislative policy and power ascribing road safety to police is approved by His Majesty and issued to the General Inspector of Police and Customs. The traffic law was established by Royal Decree number 37 in 1973, and several modifications have since followed. The current operational Traffic Law and Executive Regulations was issued in 1993.

There is an established and growing body of international research highlighting the factors that influence traffic policing (McTiernan & Levasseur, 2013; Sharma & Burnett, 2012; Baker, Schaudt, Freed & Toole, 2012 and Ciuta et al., 2012). However, there has been little academic research into traffic policing in Oman and, importantly, no identifiable research into policing strategies and practices in Oman. Although over six million traffic offences were issued in 2014, there were still 757 fatal crashes causing 913 deaths and a further 10,000 injuries (Directorate General of Traffic, 2014). Thus, despite a high level of traffic enforcement, it has insufficient impact on road user behaviour. There is a need to examine traffic policing in Oman.

Recent evidence suggests that deterrence based approaches are valuable in improving traffic policing in a number of areas, including speeding, seat belt usage and fatigue (Bates, Soole & Watson, 2012). Many researchers have argued that policing strategies built around deterrence theory are essential for effective management of specific driving populations (Armstrong, Watling & Davey, 2014). As such, deterrence theory remains a cornerstone of many contemporary initiatives to reduce fatalities on public roads and to create effective enforcement strategies and practices (Davey & Freeman, 2011; Al-Azri & Al-Manari, 2011).

Every organization has structural and resource elements which can influence its achievement (Prebble, 2012). As such, it is important to understand how organizational factors influence the performance of the ROP and the manner in which officers undertake their responsibilities.

Moore (1995) developed the strategic triangle Model to explore the achievement of public organizations. Alford and O'Flynn (2009) stated that the basic structure of the original model contained three main elements. These were (1) 'public value', which represents the purpose, aims, goals and responsibilities of the organization; (2) 'authorizing environment', which refers to the legitimacy and support that serves to achieve the public value; and (3) 'operational capability', which reflects the resources used to achieve the public value of the organization. When considering this model, it is evident that there is a need to understand the overall objective, or public value, of the ROP. Royal Decree 35/90 states that the objective of the ROP is primarily to maintain security and public order. This can primarily be achieved through deterring road users from breaking traffic laws. When this is applied to road safety, it can be seen that the overall aim of traffic policing (their public value) is ensuring the security of road users and the orderly use of the road. There is also a need to understand factors that influence of the traffic law in providing support and legitimacy to policing activities. Finally, there is a need to understand the capability of ROP to achieve their organizational goals with respect to traffic policing. Thus, using the strategic triangle model, it is expected that if members of the ROP have a strong understanding of their overall goals, have an authorising environment that supports the achievement of these goals, and has sufficient capability, they will achieve a high level of performance in terms of achieving road safety and orderly use of the roads through implementing deterrence.

Semler's alignment model (1997) is commonly used to investigate and identify organizational efficiency. The model was introduced in 1988 by Nadler and Tushman, who believed that all the aspects in the organization must fit together. This model was based on the premise that there is a positive correlation between the degree of congruence within the organization's components and their efficiency. Semler (1997) suggested that the alignment model could be used to examine an organization's design, strategy and culture to achieve desired aims. Well-designed organization's should aim to align their structures and systems, strategy and culture with the overall vision of the organisation, ensuring efficient performance (Hart et al., 2003). In the present context, the alignment of organisational structures and systems within the ROP is important to ensure the use of operational capability to achieve the public value of the organisation. Thus, the alignment model serves to aid investigating the influence of the organizational structure of the ROP on their achievement.

In line with the previous discussion, this research seeks to achieve a greater level of understanding of the influence of authorizing environment and operational capability of the ROP on the achievement of their public value. This study will also help to identify potential organisational barriers and facilitators to traffic policing in Oman, and provide a baseline to develop future policing initiatives.

Material and Method

Design:

The study was comprised of semi-structured face-to-face interviews. The interviews were directed to three levels of the police organization in Oman (e.g. executive level, supervisory level, operational level).

Participants:

A purposive sampling approach was used in data collection. A purposive sample is a non-representative subset of some larger population, and is selected to serve a very specific need or purpose (Boyce & Neale, 2006). Participants were selected according to their positions in the ROP and their job descriptions. Two police officers were from the executive level, seven police officers from the supervisory level, and ten police officers from the operational level. While the sample size may seem small, in the top two levels, interviews were conducted with over 75% of the officers in these positions. The interviews in the third level were conducted until the research reached apparent saturation.

Interview Protocol:

Three different interview discussion guides were developed by the research team. Each interview discussion guide was designed for a level of ROP's organization. The discussion guides consisted of 9, 15 and 22 items (executive, supervisory and operational levels respectively) and aimed to gather participant's perceptions regarding the components of the strategic triangle and alignment models, and their effect on ROP achievement of road safety. The interview guides were initially written in English and then translated into Arabic. The Arabic-language guide was then reviewed by several native Arabic speakers for clarity and comprehension.

Methods:

Pilot interviews were conducted to ensure the appropriateness of the questions and if any modifications were required, as well as to provide an estimate of the duration of interviews. A participant information form was administered during the commencing of the interviews to ensure informed consent. Face-to-face interviews then followed in Arabic (most of the interviewees speak only Arabic).

The interviews started with the highest level of the ROP (e.g. executive level). Once the interviews were conducted, data was analysed and, where appropriate, additional questions were added to the interview protocol for supervisors. This process repeated for the supervisory and operational levels. Each interview took approximately 45-60 minutes. While some interviews took place at the Traffic Safety Institute in Muscat, most of the interviews took place at the interviewed officer's traffic departments. The principle author, who is a member of the ROP, had an existing relationship with the majority of the interviewees, which might have influenced the collected data. To avoid such influences, participants were informed of the purpose of the research and encouraged to answer honestly without fear of repercussion (this project was also subject to ethical review to ensure no coercion was present in the methodology). After conducting every interview, prior to the analysis, the collected data was reviewed by a number of traffic police officers and the research team, and the interview protocol was revised and updated.

Thematic analysis was employed to first categorise responses using the theoretical constructs and then to identify subthemes within the data. As suggested by Muller, Maclean & Biggs (2009), the responses to key questions and direct quotes are provided to give a direct voice to the participants and clarify their individual perspective.

Results

The participants were generally quite responsive to all questions and highlighted some significant factors that influence the policing strategy and practices. The results were categorized according to the components of the used models (public value, authorizing environment, operational capability etc.). For the reporting of quotes in the results, and to protect participant confidentiality, participants are identified as "P#".

There were mixed response towards the perceived public value of traffic policing. Officers at the executive level revealed that saving lives and setting rules and regulations forms the main objective of traffic policing in Oman. Executive officers indicated that all traffic officers were aware of the ROP's goals with respect to traffic policing. In contrast, traffic officers at the lower two levels suggested that the role of traffic police officers was unclear. Despite the controversy in understanding the public value of the ROP, there was some congruency between officers that enforcement through issuing traffic offences represented the primary task of traffic police. In general, responses like "*I have to issue the biggest number*" (P15), "*issuing fines is my job*" (P14) and "w*e are prized if we issue fines*" (P13) indicated that issuing fines was the main applied method to achieve the public value with respect to traffic policing. The following are representative responses:

> *I don't know what is the role of ROP … I know that I have to issue traffic fines … this is my role* (P18)

> *We have been told that we have to issue fines … no one ever explain to me the role of ROP … I think the role of ROP with respect to road safety is to issue fines* (P17)

> *What I know is issuing fine is the priority of my senior officers … so this is what I do all day* (P11)

With respect to the authorizing environment, the supervisory officers' identified problems related to policy making, strategies and traffic law. The majority of the supervisory officers indicated that the level of deterrence in the existing regulations was too low. It was indicated that traffic sanctions were not severe enough to deter road users from violating traffic laws and regulations (these sanctions are prescribed by the law and traffic police officers have no choice regarding fine severity). In the same way, the majority of officers explained that swiftness had been neglected by the traffic law, in which traffic offences are to be paid at the time of the annual renewal of the vehicle's registration. A number of officers commented that if the rules do not deter drivers, then there is no use applying them. The following two excerpts demonstrate officers' perspectives regarding traffic law:

> *Traffic law does not have severe punishments … we apply its rules, but that does not achieve road safety* (P5)

> *Road safety requires severity … we do not have this in our policing practises* (P9)

With regards to the ROP's operational capability, executive police officers claimed that the majority of traffic police officers are capable and have the needed skills, knowledge and abilities to undertake effective traffic policing. Executive officer indicated that the nature of training programs given to traffic officers gives them confidence in their skills and abilities. On the contrary, the majority of traffic police officers at the supervisory and the operational level reported that traffic police were not equipped with the needed skills, knowledge and abilities to undertake their responsibilities. These officers indicated that they also lack the needed tools that facilitate the achievement of the public value of ROP with respect to traffic policing. Officers indicated a need for weighing scales, radar guns, breathalyzers and tyre measurement devices. In further contradiction to executive officers, the majority of traffic officers in the supervisory level indicated that current training programs have no influence on their skills or abilities. Finally, supervisory and operational traffic police officers stated that new recruits in the traffic force have a negative influence on road safety.

> *ROP expects us to create safe road environment, but they do not provide us with the needed sources … we require something more than vehicles, fuel and a set of rules* (P7)

> *To achieve that expectations of ROP, we need well- qualified human resources, finical resources and authority … we do not have that* (P3)

With respect to the perceived achievement of the public value (that is, the achievement of road safety), executive police officers believed that the majority of road users follow traffic rules and regulations. However, supervisory and operational officers revealed that road users risk their lives and the lives of others through their driving behaviours. Some of the supervisory officers elaborated that their operational officers implement reactive policing rather than proactive policing. They added that, particularly with policing of heavy vehicles, officers seek to increase fine numbers rather than strategically creating a safe road environment through targeted enforcement. It was understood that the daily practises of traffic police officers did not cover all aspects of road safety. There was a congruency between the participants that their daily policing activities were not suitable to influence the behaviours of drivers. Responses like *"we need to do more policing" (P10), "what we are doing is not enough" (P19), "it is just like if we do nothing" (P18) and "our policing should be more active" (P13)* indicated that traffic police realized the need to further develop their policing practises. In addition, the majority of supervisory and the operational officers indicated that an insufficient understanding of traffic law reduces their capabilities to achieve high level of traffic policing. The following excerpts identify these perceptions.

> *I hope that road users cooperate with traffic police officers and obligate to rules and regulations ... they can influence and improve public safety more than our police officers … we cannot assign a police officers with every driver, but we are working to make every driver a police officer* (P1)

> *Drivers keep in making the same fines … they do not know why some actions are illegal … traffic police officer never provide awareness to the drivers, simply because they do not know how... Most of the traffic police cannot identify the violations of heavy vehicles* (P13)

The interviewees highlighted a number of organizational factors which help to explain the current level of achievement. As stated before, there was disagreement regarding the quality of training. The executive officers responded that ROP has designed a variety of effective traffic training programs. In contrast, officers at the supervisory level indicated that the nature of the provided training programs is insufficient and does not help to improve the skills of traffic police officers. Further, many operational officers indicated that they would be willing to attend the provided courses but were not allowed to do so by their supervisors, due to reasons including the length of the course period, workload and a shortage in human resources. In addition, the way in which policing practices and activities are designed was a potential barrier to achievement. It was understood from the participants' responses that the current policing strategies fail to accommodate for heavy vehicle safety. Responses like *"we cannot stop them"(P16)*, *"they made that same violations again and again"(P14)*, *"new procedures should be followed"(P13)*, "*our strategies are not even useful to stop the violations of light vehicles" "(P17)* and *"I think our practises and strategies are out of date" (P12)*, indicated that new strategies should be implemented that are applicable to all vehicle types. While executive officers stated that they design traffic related activities with the participation of supervisory officers, these officer denied that this was the case.

The majority of the participants also highlighted that the executive officers focused on punishment more than rewarding or positive motivation. While supervisory officers insisted that they value using positive motivation to achieve the public value of traffic policing, operational officers indicated that their supervisors did not make efforts to motivate their officers to undertake their responsibilities in an effective way. Operational officers suggested that even having their work acknowledged could have positive impact on the willingness of police officer to undertake traffic policing in a proper way.

> *If they want us to work they have to motivate us … for me 'thank you' or 'you have done a good job' is more than enough … we don't even get these encouraging words* (P18)

> *I worked in an enforcement team for nine months … when we accomplished our mission, they told me to go back to my division without a word of thanks* (P16)

> *We work to serve our country, but still senior officers have to appreciate what we are doing* (P13)

It was interesting to note that the culture, traditions and habits of officers have a negative influence on traffic policing. Supervisory officers suggested that the culture and tradition of being friendly and helpful negatively influences road safety. For example, it was indicated that operational officers turned a blind eye to the violations of road users as a way to help them. In addition, operational officers stated that traffic policing practices were only designed for light vehicles. For instance, some of the operational officers elaborated that the insufficiency of traffic policing practices is the key element that influence their willingness to address heavy vehicles. Finally, operational officers explained that in order to achieve the desired public value, all ROP personnel (i.e. general duties police as well as traffic police) should be involved in traffic policing practices, as highlighted in the following quotes.

> *The problem with traffic police is that they cannot distinguish between policing and their tradition … that is why we do not let them work in their governorates* (P9)

> *We expect that heavy vehicles' drivers follow the safety procedures of their companies … that why we usually do not deal with them* (P15)

> *Traffic policing is the responsibility of all officers in ROP … everybody think that traffic police can manage the situation by themselves* (P12)

Discussion

To date, there is a gap in knowledge of traffic policing in Oman and the influence of organisational factors on traffic policing strategies and practices. The study utilised Moore's (1995) strategic triangle model and Semler's (1997) alignment model to explore the perceived public value (primary purpose) of the ROP's traffic police, the extent to which they achieve this public value, and the legal and organisational factors that influence this performance.

The first key theme that emerged related to police officer understanding of the public value of Royal Oman Police with respect to road safety. While the primary purpose of the ROP is to ensure security and order (road safety in this case), it was evident that not every member of the ROP knew the overarching objectives of traffic policing. Participants from the executive level assumed that traffic police officers were aware of the expectations and goals of the ROP, however, this was not the case in the other two levels. Without knowing the primary goal of traffic policing, officers are unlikely to see the benefit of what they are asked to do, and thus less compliant.

With regards to the authorising environment surrounding the ROP, it was evident that the existing traffic laws do not provide sufficient legitimacy and support to ensure deterrence of unsafe road behaviours. The majority of participants agreed with the need for severity and swiftness of sanctions, but felt that it was lacking in the current traffic law. As such, there is a lack of legitimacy and support in the current traffic law to facilitate the achievement of the public value of the ROP (to ensure safety of road users).

Regarding the operational capability of the ROP, there were conflicting responses from participants in both the executive and supervisory levels about the skills, attitudes and knowledge of traffic police officers. According to participants from the executive level, officers were well qualified to undertake their responsibilities. In contrast, the participants at the supervisory level stated that most of traffic police officers need to develop the level of their skills, attitudes and knowledge to be able to undertake the policing of road safety. Thus it was indicated that there was insufficient operational capability to achieve the public value of the ROP with respect to road safety.

Given the lack of agreement regarding the purpose of traffic policing, weaknesses in the traffic law, and lack of sufficient capability, it can be expected from the strategic triangle model that the ROP would have limited success in achieving their public value (road safety). This was supported by the responses of participants. While participants at the executive level believed that traffic police officers were positively influencing road safety, participants at the supervisory and operational level indicated that policing either fails to influence road safety, or has a negative effect. This highlights the need to address police capabilities and the level of deterrence in the current traffic law.

Within the current research the alignment model was used to identify organisational structures and systems which serve to facilitate or hinder the ROP in achieving road safety. There were a number of organisational issues raised by participants. The supervisory and operational officers indicated that a low understanding of their responsibilities and unavailability of well-structured policing strategies presented clear barriers to policing of road safety. This indicated that there were communication issues within the ROP. According to the alignment model, a firm understanding of the vision, values and purpose of the organisation and effective communication and both important to ensure organisational efficiency. The extracted data showed that it is necessary to establish a clear role of traffic police officers with respect to road safety in order to achieve their public value.

In the same way there was a congruency in the need of developing the training of traffic police officers. Despite executive officers indicating that the current training was effective, participants at the supervisory and operational level indicated that training was insufficient and inaccessible. The findings underscore the on-going need to develop training programs and requalify traffic police officers at the aspects related to road safety. Together, these issues in communication and training indicated key weaknesses in the factors of the alignment model, reducing the alignment between the vision, values and purpose of the ROP and police behaviour and achieving road safety.

Further Directions and Conclusion

The findings of the analysis highlighted a number of key directions for future research. There is a need for exploring the process of creating and communicating traffic policing related goals in order to achieve the core objectives of traffic policing. In the current traffic policing strategies and practices, traffic policing goals are unclear to officers, and this appeared to negatively influence the achievement of road safety. There is also a need for research to examine the training of traffic police officers to better qualify traffic police officers to achieve their public value with respect to traffic policing. Further, there is a need to continue investigating the impact of the ROP organizational structure and systems on road safety in Oman in order to identify approaches to improve policing of road safety.

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Social Influences on Risky Driving Behaviours among Young Drivers in Oman

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Abstract

Young drivers represent approximately 20% of the Omani population, yet account for over one third of crash injuries and fatalities on Oman's roads. Internationally, research has demonstrated that social influences play an important role within young driver safety, however, there is little research examining this within Arab gulf countries. This study sought to explore young driver behaviour using Akers' social learning theory. A self-report survey was conducted by 1319 (72.9% male and 27.1% female) young drivers aged 17-25 years. A hierarchical regression model was used to investigate the contribution of social learning variables (norms and behaviour of significant others, personal attitudes towards risky behaviour, imitation of significant others, beliefs about the rewards and punishments offered by risky behaviour), socio-demographic characteristics (age and gender), driving experience (initial training, time driving and previous driving without supervision) and sensitivity to rewards and punishments upon the self-reported risky driving behaviours of young drivers. It was found that 39.6% of the young drivers reported that they have been involved in at least one crash since the issuance of their driving licence and they were considered 'at fault' in 60.7% of these crashes. The hierarchical multiple regression models revealed that socio-demographic characteristics and driving experience alone explained 14.2% of the variance in risky driving behaviour. By introducing social learning factors into the model a further 37.0% of variance was explained. Finally, 7.9% of the variance in risky behaviour could be explained by including individual sensitivity to rewards and punishments. These findings and the implications are discussed.

Introduction

The overrepresentation of youth in traffic crashes is a global road safety problem. Road traffic injuries are estimated as the leading cause of death among young road users aged 15-19 years and the second leading cause of death among those aged 20-24 years (Toroyan & Peden, 2007). Accounting for 10% of the population in the OECD countries, 27% of crash fatalities occurred among young road users aged 15-24 years (Organization for Economic Co-operation and Development, [OECD], 2006). The situation in Oman is not dissimilar with traffic crashes forming one of the main threats to life within the young population. Young road users aged 16-25 years have the highest magnitude of road mishap in Oman. They represent approximately 20% of the Omani population, yet account for 37% of crash injuries and 31% of crash fatalities on Oman's roads (Royal Oman Police, 2014).

Epidemiological evidence regarding the occurrence of risky driving behaviours amongst young drivers is concerning (Ivers, Senserrick & Boufous et al., 2009; Williams, 2006). Researchers have focused on the vast range of factors that are likely to impact young driving behaviour particularly during the early driving period. Akers' Social Learning Theory (SLT) is one of the psychosocial theories that emerged within the criminological domain to provide a better understanding of the initiation and maintenance of deviant behaviour. It is a broad-based theory that mainly focuses on the social reinforcement of the behaviour assuming that deviant and conforming behaviour are produced through a similar learning process that operates in a context of social structure, interaction and situation. It is a general theory that can be utilized to understand the learning process of several types of deviant behaviour (Akers & Sellers, 2004).

The concept of Akers' SLT operates within four fundamental social variables that influence the likelihood of the deviant or conforming behaviour occurring including differential association, definitions, imitation and differential reinforcement. Engaging in deviant behaviour is more likely when individuals interact (i.e. differentially associate) with significant others who promote, accept or engage in such deviant behaviour. Differential association with intimacy groups initiates the social context for the exposure to other's norms, attitude and orientation (i.e. definitions or personal attitude) which in turn leads individuals to acquire their own definitions. They reflect the one's beliefs (both general and specific) about what is considered appropriate behaviour. Modeling of significant other's behaviour is referred to as imitation which is essential for the initiation of the behaviour, while, the continuity of the behaviour is dependent on the anticipated social and non-social consequences and is referred to as differential reinforcement. It is the balance between anticipated rewards (i.e. favourable consequences) and anticipated punishments (i.e. unfavourable consequences) (Akers & Sellers, 2004).

Akers' SLT has been tested with a large number of scholars on a range of deviant behaviours including adolescent substance users (Hwang & Akers, 2003; Bonino, Cattelino, & Ciairano, 2005) and adolescent smoking cessation (Chen, White, & Pandina, 2001). In the field of road safety, DiBlasio (1987) found a significant relationship between the four concepts of Aker's SLT and the choice of American youths aged less than 15 years to travel as passengers with drinking drivers. Watson (2004) demonstrated differential association to be the strongest predictor of unlicensed driving among Australian's adults. Fleiter and Watson (2006) revealed that differential association, definitions and punishment were the most significant predictors of speeding behaviour among drivers aged 17-79 years. Among learner driver, Bates, Watson and King (2009) verified that behavioural differential association of friends, definitions and anticipated reward were the most significant social predictors for their compliance to the law, while, for their future driving intention only anticipated reward was the most social predictors. In the prediction of self-reported risky driving behaviours among young new drivers aged 17-24 years, Akers' SLT constructs were able to explain additional 42% of the variation above and over the sociodemographic characteristics with imitation, anticipated reward and anticipated punishment were the significant predictors (Scott-Parker, Watson & King, 2009).

Akers' theory focuses mainly on the balance between anticipated reward and punishment as a reinforcement of the behaviour. Thus, investigating personality differences in the sensitivity to rewards and sensitivity to punishments could advance the use of Akers' theory. According to the reinforcement sensitivity theory (RST) of personality (Gray, 1993), two neurological mechanisms are thought to regulate individual's behaviour. The behavioural approach/activation system (BAS) is thought to regulate an individual's sensitivity to reward, while the behavioural inhibition system (BIS) is thought to regulate an individual's sensitivity to punishment. Response variations between the two systems yield the personal differences that motivate the engagement in certain behaviour (Corr, 2008; Vermeersch, Kaufman & Houtte, 2013). The most recent attempt to measure the two behavioural systems influence was made by Carver and White (1994). They developed a validated tool to examine the personal difference according to the function of the two systems guided by the principles of Gray's theory. The scale has been used widely in order to investigate a number of risky health behaviours (Davis, Patte & Levitan et al., 2007; Danielle, James & Kurt et al., 2009). Recently, Scott-Parker, Watson, King and Hyde (2013) found sensitivity to reward was a strong predictor of risky driving behaviour among novice drivers.

Theoretical investigation of risky driving behaviours as mentioned in the literature has been guided successfully by Akers' theory and personality theory. Thus, it is hypothesized that the utilization of both theories could yield a better insight into the risky driving behaviour within the context of young Omani drivers. The general aim of the research was to identify the influence of social learning variables, sensitivity to reward and punishment, and socio-demographic characteristics on the risky driving behaviour among Omani young drivers.

Methods

A cross-sectional survey was conducted within the period from January to March, 2015 to investigate the social influence upon risky driving behaviours among young Omani drivers. A total of 1319 Omani young drivers (72.9% males & 27.1% females) aged 17-25 years (M=21.8, SD=2.1) with a valid driving licence volunteered to participate in the study from all over Oman. Oman does not have a graduated licencing system so all participants held a full, non-restricted, driver's licence, which they received after passing driving tests while holding a learners' license. A convenience snowballing sampling technique was used extensively to get access to the widely distributed young drivers. A number of students from Sultan Qaboos University (SQU), who lived in the 11 different governorates of Oman were recruited to distribute the questionnaires in their governorate. These students also recruited others from different areas within these governorates to further distribute the questionnaire. These individuals distributed the questionnaires through personal contacts (in villages, sport clubs, colleges, work places in these governorates etc.), allowing access to a broad range of participants in the general population. Further, this ensured the participation of a range of people with different driving experiences and socio-demographic backgrounds. All participants responded anonymously, and the study received ethical approval from the Ethics Committee at the college of medicine and health science, SQU (MREC#733).

To achieve the objectives of the study, a self-reported questionnaire was developed. It consisted of four dimensions: socio-demographic characteristics, risky driving behaviour, social learning variables, and sensitivity to reward and punishment. The risky driving behaviour scale consists of 39 items tapping various types of common on-road risky driving behaviours. A list of items measuring common risky driving behaviours was developed guided by literature review and Oman's traffic regulation. These questions were drawn from past research using the driver behavior questionnaire (Al Reesi, Al Maniri & Plankermann et al., 2013; Scott-Parker, 2012). Participants were asked to provide a judgment on the question "In the last twelve months, how often have you done the following behaviours while driving?" on a Likert-type scale ranging from 1 (never) to 5 (Always). Steps were undertaken to ensure the content validity of the list including face validity (i.e. experts' opinions) and a pilot study (i.e. receiving comments from participants), and then the final draft was prepared. Participants were also asked to provide their judgement on 38 items measuring the four social learning variables: differential association (12 items), definitions (personal attitudes, 9 items), imitation (3 items) and differential reinforcement (rewards (7 items), punishments (7 items). Finally, they were asked to provide their judgement on 14 items measuring the sensitivity to rewards (7 items) and punishments (7 items) resulted from involvement in risky driving behaviours. The social learning theory and sensitivity to rewards and punishments questions were also drawn from past research using these theories for young drivers (Scott-Parker, 2012) and modified for the Omani context. The reliability of all scales (one for behavior, and one for each aspect of the two theoretical constructs) was checked using Cronbach's alpha and is presented in the results section.

The Statistical Package for the Social Sciences (SPSS) version 21 was used in the analysis of the data. The internal consistency of the study scales was evaluated through Cronbach's alpha coefficient. Descriptive statistics of the scales were calculated including mean, standard deviation, skewness and kurtosis. Bivariate correlations were conducted using Pearson's product moment correlation coefficients. Independent sample t tests and one way ANOVA were used as required. A hierarchical regression model was used to investigate the contribution of social learning variables and sensitivity to rewards and punishments (while controlling for socio-demographic characteristics) upon the self-reported risky driving behaviour of young drivers. As the goal of this analysis was to determine the benefit of using these theories in the Omani context, rather than create a single predictive model, this technique was deemed more suitable than alternative approaches. For the first step socio-demographic variables were added, followed by social learning variables and finally sensitivity to rewards and punishments. The contribution of each theory was measured R2 change. After these three steps, a fourth step was added in which variables which were not significant predictors at step three were removed and the unique contribution of each variable was examined using semi-partial R2.

Results

Descriptive statistics of the study scales

Table 1 depicts the descriptive statistics of the study scales. The distributions of the scales were approximately symmetrical to slightly skewed with skewness ranged between -0.54 and 0.58 and mesokurtic (normal) in shape with kurtosis ranged between of -0.41 and 0.57. All scales showed a good internal consistency with Cronbach's alpha values ranged between (α=0.72) and (α=0.94). Young drivers reported more anticipated punishment (*M*= 24.79) than anticipated rewards (*M*=16.41). In addition, they reported more sensitivity to punishment (*M*=18.99) than sensitivity to rewards (*M*=16.31).

Table 1. Number of items, Cronbach's alpha, means, standard deviations, means per item, Skewness and Kurtosis for the study scales.

Social variables	N. Items	Cronbach's alpha	Mean	SD	Mean per item	Skewness	Kurtosis
RDB	39	0.94	93.98	24.77	2.41	0.58	0.57
DA	12	0.86	30.64	8.86	2.55	0.321	0.125
Attitude	9	0.90	21.16	7.83	2.35	0.400	-0.272
Imitation	3	0.72	6.71	2.69	2.24	0.544	-0.153
Reward	7	0.92	16.41	6.85	2.34	0.487	-0.411
Punishment	7	0.91	24.79	6.94	3.54	-0.545	-0.306
SR	7	0.87	16.31	6.12	2.33	0.46	-0.26
SP	6	0.77	18.99	4.99	3.17	-0.19	-0.26

RDB: *Risky driving behaviour****,*** ***DA:*** *Differential Association,* ***SR:*** *Sensitivity to Rewards,* ***SP:*** *Sensitivity to Punishment*

Risky driving behaviours according to the socio-demographic characteristics

Table 2 presents the distribution of drivers in the study sample according to their socio-demographics and the bivariate analysis with risky driving behaviour. Males reported significantly higher levels of risky driving behaviour than females. The level of risky driving behaviour significantly decreased with increased age. Unmarried drivers reported significantly higher level of risky driving behaviour compared to married drivers. Unemployed young drivers reported higher level of risky driving behaviour compared to employed drivers. Drivers initially trained by drivers other than official instructors (i.e. family members or friends) showed higher level of risky driving behaviour compared to drivers trained under official driving instructors (i.e. those that hold training licence). Drivers with prior history of unsupervised driving before receiving an open licence (including both unsupervised driving before and after receiving a learner's licence) showed a higher level of risky driving behaviour than drivers without prior history of unsupervised driving. The level of risky driving behaviour significantly increased with both years of driving experience (years since receiving an open licence) and weekly hours of on-road driving. In addition, crash involvement was statistically associated with higher reported levels of risky driving behaviour.

Table 2. Socio-demographic Characteristics (frequency and percentage) and the association with risky driving behaviour.

Characteristics	Frequency (1319)	Percent (%)	Risky Driving Behaviour (RDB)		
			Mean	SD	Sig*
Gender					
Male	962	72.9	96.7	24.0	(t=6.59, p<0.01)
Female	357	27.1	86.7	25.5	
Age					
17-19 Yrs.	205	15.5	98.4	27.0	(F=11.34, p<0.01)
20-22 Yrs.	623	47.2	95.7	24.8	
23-25 Yrs.	491	37.2	90.0	23.2	
Marital Status					
Single	1032	78.2	95.4	24.5	(t=3.94, p<0.01)
Married	287	21.8	88.9	25.3	
Working Status					
Unemployed	691	52.4	96.3	24.9	(t=3.51, p<0.01)
Employed	628	47.6	91.5	24.4	
Initial Driving Instructor					
Official Driving Instructors	564	42.8	88.4	23.7	(t=-7.17, p<0.01)
Other	755	57.2	98.1	24.8	
Prior Unsupervised Driving					
Yes	597	45.3	100.6	23.6	(t=9.02, p<0.01)
No	722	54.7	88.6	24.4	
Driving Experience in Years					
(0-1.99) Years	512	38.8	91.8	25.0	(F=3.73, p=0.024)
(2.00-3.99) Years	484	36.7	94.6	23.7	
(> = 4.00) Years	323	24.5	96.5	25.8	
# of Driving Hours per					
0-3 hours	259	19.6	88.1	24.9	(F=18.69, p<0.01)
4-7 hours	436	33.1	92.1	23.5	
8-11 hours	291	22.1	91.9	22.2	
12-15 hours	149	11.3	98.7	24.3	
>= 16 hours	184	14.9	106.4	27.0	
Crash History					
Have been Involved	522	39.6	96.7	24.2	(t=3.21, p<0.01)
Never been Involved	797	60.4	92.2	25.0	

Correlation between risky driving behaviours, social learning variables, and sensitivity to rewards and punishments

Pearson's product moment correlation coefficients between the study scales are shown in Table 3. Risky driving behaviour (RDB) was positively correlated with differential association, attitude, imitation and reward while it showed insignificant negative correlation with punishment. All correlations between the four social learning variables and the two types of personality, sensitivity to rewards (SR) and sensitivity to punishment (SP), were significant and they were positively correlated while it was negatively correlated between sensitivity to rewards and anticipated punishment. Risky driving behaviour correlated positively with both sensitivity to rewards (SP) and sensitivity to punishment (SP).

Table 3. Correlations between social learning variables, sensitivity to rewards and punishments, and risky driving behaviour.

	1	2	3	4	5	SR	SP	RDB
1- D.A	-							.57**
2-Attitude	.66**	-						.63**
3-Imitation	.71**	.63**	-					.56**
4-Reward	.57**	.55**	.57**	-				.51**
5-Punishment	.05	-.16**	-.11**	-.07*	-			-0.03
SR	.52**	.63**	.55**	.55**	-.12**	-		.69**
SP	.22*	.06*	.06*	.10**	.36**	.17**	-	.18**

** p<0.05, ** p<0.01*

Psychosocial influences on risky driving behaviours

A hierarchical regression was conducted to assess the influence of socio-demographics (step 1), social learning variables (step 2), sensitivity to rewards and punishments (step 3) on risky driving behaviours among young Omani drivers (Table 4). In the first step, the model was significant with the socio-demographics and explained 14.2% of the variance. In the second step, the social learning variables were incorporated into the model and explained additional 37.0% of the variance. In the final step, incorporating sensitivity to rewards and punishments into the model explained additional 7.9% of the variance. Overall, the final model was significant and explained 59.1% of the variance in risky driving behaviours and the significant predictors were differential association, attitude, imitation, rewards, punishment, sensitivity to rewards and sensitivity to punishment, gender, age, prior unsupervised driving, driving experience and driving hours. Examining the unique contribution of significant predictors, Sensitivity to rewards was the strongest predictor and uniquely explained 6.9% of variance in young driving behaviours followed by attitude which explained 1.6% of variance.

Table 4. Hierarchical multiple regression results for the three analyses predicting self-reported risky driving behaviour by young drivers

Model	**Step 1**		**Step 2**		**Step 3**		**Step 4*****		
	β	**Sig.**	**β**	**Sig.**	**β**	**Sig.**	**β**	**Sig.**	sr^2
Socio-demographics									
Gender	-.053	.058	-.042	.049	-.044	.025	-.044	.004	.002
Age	-.166	.000	-.088	.000	-.068	.002	-.073	.009	.004
Marital Status	-.045	.108	.005	.808	.016	.407	-		

Working Status	-.065	.023	-.038	.076	-.031	.119	-			
First Driving Instructors	.094	.001	.016	.466	.016	.429	-			
Prior Unsupervised Driving	-.142	.000	-.085	.000	-.062	.002	-.067	.009	.004	
Driving Experience	.130	.000	.072	.002	.063	.003	.062	.007	.003	
Driving Hours	.178	.000	.121	.000	.095	.000	.093	.019	.008	
Social learning variables										
Differential Association	-	-	.115	.000	.092	.002	.094	.008	.003	
Attitude	-	-	.322	.000	.193	.000	.196	.037	.016	
Imitation	-	-	.178	.000	.118	.000	.116	.013	.006	
Reward	-	-	.134	.000	.051	.033	.051	.003	.001	
Punishment	-	-	.059	.004	.050	.013	.047	.004	.002	
Sensitivity to rewards and punishments										
SR	-	-	-	-	.374	.000	.373	.144	.069	
SP	-	-	-	-	.052	.010	.054	.006	.002	
Adjusted R^2	0.137		.507		0.586			0.586		
R^2 Change	0.142^{**}		0.370^{**}		.079**					

Step 1: $F=27.18^{**}$, ***Step 2:*** $F=105.35^{**}$, ***Step 3:*** $F=125.43^{**}$, ***Step 4:*** $F=156.49^{**}$, * *p<0.05*, **

****** In step 4, only significant variables from step 3 included in the model, sr^2:semi-partial R^2***

Discussion

The study presents some insight into the risky driving behaviour as a main contributory factor in crash involvement among young drivers and confirmed the finding of previous research that multiple factors influence the engagement in risky driving behaviour. Socio-demographics predicted approximately 13.7% of the variance in self-reported risky driving behaviour. Risky driving behaviour decreased with age reflecting the contribution of age related factors or the maturity of young drivers as one of the reasons behind their risky driving behaviour (Ivers, Senserrick & Boufous et al., 2009; Williams, 2006). Driving experience found as a significant factor in risky driving behaviour which supports the literature findings (Al Reesi, Al Maniri & Plankermann et al., 2013). The reported on-road time of driving exposure was quite high among the current sample reflecting the level of driving conducted by young drivers due to the absence of alternative public transportation in Oman (Islam & Al Hadhrami, 2012). The study found prior unsupervised driving before licencing as a significant predictor of risky driving behaviour after licencing. This is in line with previous findings in literature (Scott-Parker, Watson & King, 2009; Bates, Watson & King, 2009). Given that nearly half of the participants reported unsupervised driving prior to receiving a licence, this represents a major concern for road safety in Oman.

All Akers' social learning variables (differential association, imitation, personal attitude, anticipated rewards and anticipated punishments) were significant predictors of the self-reported risky driving behaviours among young drivers, explaining 37.0% of the variance. In previous findings not all of the Akers' social learning variables were found as significant predictors. Imitation wasn't a significant predictor in one Australian learner drivers' study (Bates, Watson & King, 2009), while, differential association and personal attitude weren't significant predictors in an Australian novice drivers' study (Scott-Parker, Watson & King, 2009). However, the remaining factors have been shown to have a significant association with risky driving behaviour.

The anticipated reward significantly reinforced the engagement in deviant driving behaviours, which is expected based on previous findings (Scott-Parker, Watson & King, 2009; Bates, Watson & King, 2009). However, the results indicated that despite more social punishments reported than social rewards, punishments did not significantly reduce engagement in risky driving behaviour. Previous studies have demonstrated that anticipated punishments reduce drug driving (Armstrong, Wills & Watson, 2005), and speeding (Fleiter & Watson, 2006).

Reward sensitivity and punishment sensitivity explained significantly another 7.9% of the variation in the self-reported risky driving behaviour. Sensitivity to rewards as expected was strongly and positively correlated with risky driving behaviour which supports the finding of Scott-Parker, Watson, King and Hyde (2013). The sensitivity to punishment was also found to be a significant predictor, however, greater punishment sensitivity was associated with increased risky driving behaviour. This is contrary to the findings of Scott-Parker, Watson, King and Hyde (2013), who found sensitivity to punishments was insignificantly correlated with risky driving behaviour.

The combination of the findings about anticipated punishments and punishment sensitivity may indicate problems with the effectiveness of current punishments, either social (i.e. parents and peers) or non-social (i.e. police). Specifically the results showed that even though participants may expect punishment and be sensitive to punishment, the existing punishments did not deter risky driving behaviours. This may indicate a lack of severity and swiftness within the current traffic police sanctions which is expected to vary across jurisdictions. For example, in Oman offenders pay their fines when renewing the vehicle registration, and thus there can be long delays between offending and payment of fines.

Strengths and Limitations

Methodological limitations need to be considered while interpretation of the results. Data was collected through a self-reported questionnaire and thus response bias, recall bias and stability of response are of concerns. The results are representative of the young driving population participated and not the overall driving population in Oman. Notwithstanding such limitations, with the shortage in research examining young driving behaviours within the social context in Oman, the current research is expected to provide a theoretical and practical contribution to the research knowledge in the field of young driver's road safety in Oman. Based on theoretical guidance, the research is anticipated to provide further understanding of factors underlying risky driving behaviours among young drivers to be considered in future intervention.

Conclusions and Future Directions

The above discussion revealed the capacity of Akers' SLT to bring additional understanding of risky driving behaviours within Omani context as well as the inclusion of sensitivity to rewards and punishments which also gave additional benefit. Sensitivity to rewards and personal attitudes were the strongest predictors of risky driving behaviours among young Omani drivers. The role of punishments to deter the engagement in risky driving behaviours was weak and thus, required further investigation. This research is preliminary in nature within Omani context and needs to be followed by further research investigating separately the role of parents and peers as primary sources of influences as embedded in Akers' SLT. Understanding the social mechanisms through which parents and peers influence young driving behaviours is important for the interventions in this area.

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When, where and why road crashes are likely on the Kings Highway NSW?

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Abstract

Rural road crashes are a major problem in regional Australia. The reasons for these crashes are a complex interplay between human behaviour, road characteristics and environmental factors. This paper will consider the contribution that road geometry makes to the incidence of crashes involving injuries or fatalities. This relationship will be explored specifically for the Kings Highway, a major arterial road connecting the ACT with coastal southern New South Wales, Australia. It introduces a new method of plotting crashes with road segmentation calculating sinuosity index, critical visual points, and road grade as three components of road geometry within a GIS context. The traffic flows are standardised relative to volume and the data is used to ascertain whether there is any correlation between the road geometry components and crash distributions between day and night driving. The results suggest that the likelihood of a crash is higher during the day on downhill curvy segments of the road. This is not the case for night driving where the incidence of crash is similar on both straight and curved roads segments because of the headlight effect and limited background visual field.

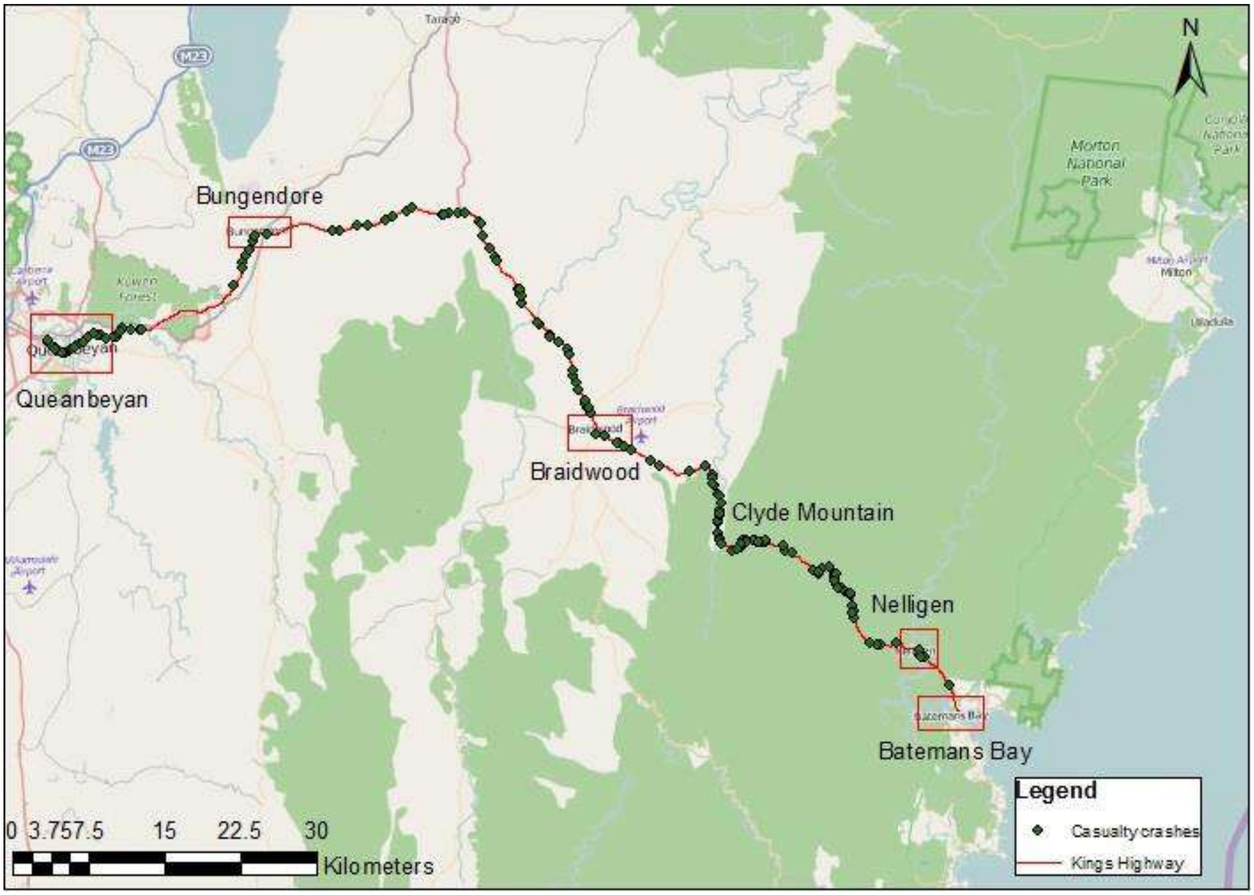
Introduction

Rural casualty crashes are a major safety problem in New South Wales (NSW), Australia (Austroads 2010a). Within the substantial literature that has sought to explore and theorise the factors contributing to road safety there is widespread agreement that human behaviour, road characteristics and the environment are the main factors that affect road safety (Shankar, Mannering et al. 1995; Elvik, Christensen et al. 2004; Wang, Quddus et al. 2013; Yu and Abdel-Aty 2014). Driver errors, in isolation or in combination with other factors, are involved in about 80% of crashes (Forkenbrock and Foster 1997). In addition to the significant contribution of driver behaviour, road geometry, traffic conditions and lighting conditions can also affect road safety (Sagberg 1999; Golob 2003). The mixed effect on road safety of some of these factors, especially traffic conditions, speed and geometry (Shankar, Mannering et al. 1995; Aarts and Van Schagen 2006; Jones, Haynes et al. 2012; Wang, Quddus et al. 2013) provides a key rationale for further research in this area.

Against this backdrop, the current paper will consider associations between key road geometry variables (sinuosity, critical visual points, and grade) and crash rates within different environmental conditions (day/night, eastbound/westbound), along Kings Highway, NSW. The overarching research question is: when, where and why are crashes likely on Kings Highway? The latter is a main rural road, around 132 km in length that connects Queanbeyan, on the border of the ACT, to Batemans Bay, a coastal town in NSW. The road provides residents of the ACT with their primary means of accessing a range of holiday, recreation and leisure destinations along the scenic south coast of NSW. Bungendore and Braidwood are the main towns along the road. In recent years, there has been a slight increase in casualty crash rates along Kings

Highway, resulting in a road safety review and ongoing upgrades (RMS 2013). Figure 1 illustrates the Kings Highway route and casualty crash locations from 2007 to 2011.

Figure 1. Crash distributions along Kings Highway, 2007-2011



Method

In the literature, the most common methods used for crash analysis are crash frequency and crash rate methods (Mannering and Bhat 2014); the particular approach that is employed will be dependent upon data availability and project aims and objectives (Yu, Liu et al. 2014). The data used for this study was 5 years of casualty crash and traffic count data sourced from the NSW Department of Roads and Maritime Services (2007-2011). While the quality of this data was generally very good, it did have the limitation of not identifying crash types. To analyse this data, crash frequencies and crash rates were determined, and associations with driver gender, age and speed were explored, including differences (if any) between day/night, and eastbound/westbound driving directions (Night was considered as extending from 6pm to 6am i.e. when headlights are generally used).

In terms of road geometry analysis, data limitations imposed certain constraints on the range of methods that could be considered for the current paper. Road centreline data was supplied by the NSW Lands Department. Comprehensive geometric data concerning Kings Highway was not made available to the authors. As such, the methodology described below could be construed as a viable crash rate analysis method that might be employed when detailed road characteristic data is limited or unavailable.

Regardless of the particular methodology that is used, with respect to analysis of road characteristics segmentation is almost invariably used to extract certain road geometry variables, and to identify black spots. Within the literature, the length of road segments ranges from 500 m to 7 km (Miaou and Lum 1993; Ackaah and Salifu 2011; Mamčic and Sivilevičius 2013; Hosseinpour, Yahaya et al. 2014). For the purposes of this study, the road was divided into *n* circles and the diameter of each circle was 1 km. The latter corresponded to the straight-line distance for each road segment, entailing that the actual length of each road segment $k_n \geq 1$ km. Using this approach, the total road length (about 132 km from the last roundabout in Queanbeyan to the first roundabout in Batemans Bay) was divided into 124 segments.

Once a road has been segmented, the next task for any analysis of roach characteristics is to determine key geometric characteristics, especially those relating to curvature. Within the literature, a wide range of curvature measurements have been used in the analysis of road crashes, including bend density (the number of bends per kilometre), detour ratio (the ratio of actual road distance to straight distance), straightness index (the proportion of road segments that are straight), cumulative angle (the cumulative angle turned per kilometre), mean angle (the mean angle turned per bend) (Haynes, Jones et al. 2007). It is widely agreed that use of a single measure will not suffice to capture enough of the significant geometric characteristics for a given road.

When data sources are limited, as in the current study, determining key characteristics of the road geometry can be challenging (Barker, Farmer et al.). To partly address these challenges, the current study focuses on three key components of road geometry that have not been widely used to date. These include: sinuosity index (actual road distance to straight-line distance) (Williams 1986; Jones, Haynes et al. 2012); critical visual points (focal points, or points in a bent segment where the visual information of the driver changes due to changes in direction) (Land and Lee 1994); and grade (ratio of vertical change to horizontal change) (Austroads 2015). These features are presented diagrammatically in Figure 2, and discussed further below, in turn.

The sinuosity index is measured using equation 1; critical visual points are measured by tangent lines. They involve some sort of threshold for angular change in direction of field of view at a particular point; and grade (gradient) of the straight line is measured using Equation 2.

$$SI = \frac{\widehat{AB}}{\overline{AB}} \qquad (1)$$

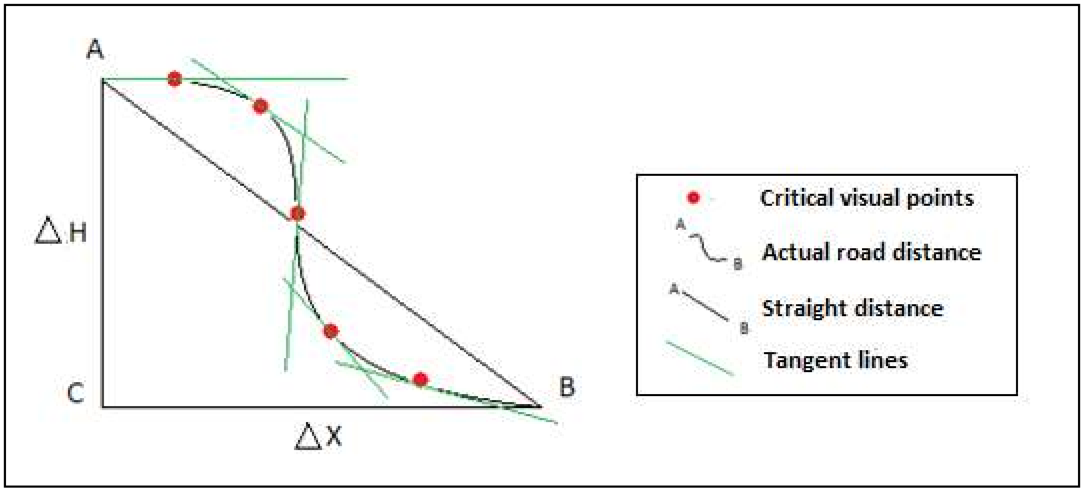
In Equation 1, SI is sinuosity index, $\widehat{AB}$ is actual road (path) length, and $\overline{AB}$ is shortest road (path) length.

$$G = \frac{\Delta H}{\Delta X} \qquad (2)$$

In Equation 2 G is gradient, ΔH is change of height, and ΔX is change of distance

The sinuosity index provides a physical measurement of road curvature. Where SI = 1, the road

Figure 2. Sinuosity Index Critical Visual Points and Grade of the straight line



segment is straight; where *SI* > 1, the road segment is curved; as the index increases, so too does the curvature of the road segment. The sinuosity index is a relatively straightforward indicator of curvature that might be usefully employed when detailed geometric data is limited. However, the index does have its limitations in so far as it is easy to imagine one long, moderate curve having greater sinuosity than a series of shorter, sharper curves. Thus, it is essential to supplement the sinuosity index with data concerning critical visual points so as to differentiate between different types of curves. Consider, for example, two road segments where the respective sinuosity indices are identical, but one has three critical visual points, the other seven. The road segment with seven critical visual points will have sharper and more frequent curves, than the segment with three critical visual points. The critical visual points measure has the additional feature of embedding a key aspect of driver behaviour in the crash analysis since critical visual points relate to the visual field of drivers. Finally, it is essential to consider grades because crash rates are different between uphill and downhill sections of road (Jurewicza, Chaub et al. 2014).

In order to examine associations between crash data and road geometry, the frequency of crashes was plotted along Kings Highway. Urban areas were excluded because they have a built-up environment, along with different road geometry features, speed limits and environmental conditions; the distinction between rural and urban roads is recognised by NSW speed zoning guidelines (RTA 2011). The results were compared between day/night (daylight and darkness) and eastbound/westbound travelling directions. The crash data were then standardised per traffic per length of segment, results were compared at an aggregated level, and clusters identified for further analysis. Correlation matrix and regression methods were used to evaluate relationships between road geometry factors and crash rates in different lighting conditions and travelling directions. Where significant correlations were identified, a geometric index was developed which might form the basis for further research and analysis.

Results

Table 1 summarises crash data results, with significant outcomes highlighted in bold. In general, Crash numbers vary by gender according to whether the travel is day/night or eastbound/westbound. There is a significant difference in the male/female ratio and younger/older drivers when comparing travel during the day and travel during the night. Young and Male drivers are far more likely to have a crash during the night than females. Number of Male to Female drivers is different travelling eastbound and westbound; specifically the ratio of number of male/female crashes travelling eastbound is more than twice travelling westbound. Nonparametric testing shows that the results are significant ($p<0.05$).

Figure 3 illustrates the relationship between sinuosity and critical points. The best fit for the relationship is via a quadratic regression rather than a linear analysis (R^2 = 0.65 and 0.58, respectively). This suggests that there is a ceiling to the impact of sinuosity on the number of critical visual points.

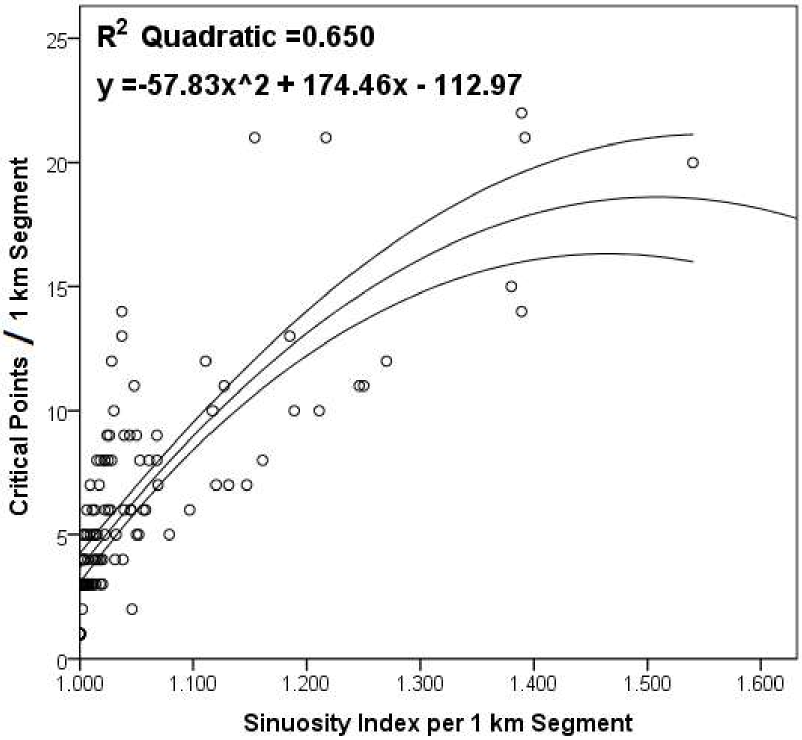
Figure 4 depicts the distribution of crash frequencies along Kings Highway, divided into 124. The X-axis summarises road centreline data measured by the methodology described above (critical visual points changes for $\overline{AB}$ =1, and $1 \leq SI \leq 1.5$), and the Y-axis illustrates sinuosity changes ($1 \leq SI \leq 1.5$) . Crash frequency distribution is compared from Queanbeyan to Batemans Bay (above the X-axis) and Batemans Bay to Queanbeyan (below the X-axis), and between day and night.

Excluding the obvious differences in crash frequencies between day and night (due to greater volumes of traffic), the most noteworthy features of the diagram are clusters during the day travelling eastbound between segments 90-110 in the Clyde Mountain area (the road section with maximum sinuosity and critical points). At night time, there are no clusters; crash frequencies at night do not seem to vary according to straightness or sinuosity. When crash rates are standardised per traffic per length and compared in aggregate, Mann Whitney nonparametric test results suggest that daytime eastbound crashes are significantly different between straight sections and curves (p<0.05); this is not the case for night crashes.

Figure 5 is a correlation matrix that summarises correlations between crashes and means for the road geometry factors, during the day and night. The results are presented at an aggregate level, where the total number of road segments is combined to form 24 sections, each section incorporating 5 segments. The aggregation of the segments into 24 x 5 km sections is intended to reflect road safety signage practices (whereby advisory signs refer to 5 km stretches of road). Significant quadratic correlations are highlighted in thick boxes. The results suggest that there is a correlation between eastbound daytime crashes and mean sinuosity, mean critical visual points, mean positive gradient (uphill) and mean negative gradient (downhill).

Figure 6 summarises relationships between crash rates and road geometry factors along Kings Highway is illustrated. In this figure, a geometrical index is used to examine a range of scenarios (day/night and eastbound/westbound) to take into account any impacts of gradient on the distribution of crash rates. The geometrical index is a multiplicative index, resulting from mean sinuosity × mean gradient. The highest index corresponds to eastbound travel during the day, and to Section 19 which encompasses the beginning segments of the Clyde Mountain area (segments 19-22). The quadratic regression analysis results suggest an improvement in R^2 value from 0.35 to 0.75 by multiplying sinuosity index by gradient.

Figure 3. Sinuosity Index and Critical Points Regression



Discussion

In this research a simple and new methodology is used to identify the differences between crash rate distribution in different road geometry and environmental conditions. The method may be most fruitfully employed when detailed road geometry data is unavailable. Sinuosity, critical visual points and gradient are the three main variables used to summarise associations between road characteristics and the distribution of crashes (frequency and rate), for day/night and eastbound/westbound travel. The visualisation and segmentation method in this research is useful for summarising crash data and road geometry factors, and suggests some early interpretations that might be explored through further research and analysis.

The main findings are that the rate of crashes is more at night; and on curves during the day, travelling eastbound, downhill. No significant difference has been found between crash rates on straight sections and curves at night. The high crash rates at night may be due to speed (Fildes, Leening et al. 1989), lack of visual field (Plainis, Murray et al. 2006), voluntary risk taking of the driver (Konstantopoulos, Chapman et al. 2010) and driver age and experience (Underwood, Chapman et al. 2002). The results for daytime, eastbound, downhill travel suggests that road geometry has a stronger influence on crash rates on curves (Jurewicza, Chaub et al. 2014), in combination with the road environment and driver behaviour. The absence of a significant difference between crash rates on straights and curves at night, may be linked to a constrained visual field due to headlights (Aarts and Van Schagen 2006) and/or limited visual cues in the visual field (Fildes, Leening et al. 1989; Baker 1999; Plainis, Murray et al. 2006;

Konstantopoulos, Chapman et al. 2010). In summary, while curvature can increase crash risk, decreased visual field due to the darkness has a greater effect, producing more random crashes at night, and more clustered crashes on curves during the day.

As crash rates or clusters increase in a specific road segment, road safety might decrease and actions such as road upgrades, changing speed limits and/or additional police enforcement might be required. However, the findings reported here indicate that crash rates vary significantly, not only according to different road geometries, but also in different environmental conditions. This suggests that further consideration might be given to greater utilisation of variable speed limits.

Crash numbers for males and females differ significantly between day/night and eastbound/westbound travel. The results are statistically significant. This may be due to psychological and physiological differences between male and female drivers as discussed in previous studies. Young male drivers are more responsible for night and loss of control crashes because of speeding, risk taking, and the way they use roads (Clarke, Ward et al. 2006). different crash numbers for males and females travelling eastbound and westbound might be due to differences between male and female driving skills (Laapotti and Keskinen 1998). Some further research is required in this area.

In conclusion apart from the significant effect of road characteristics on road safety, it is necessary to evaluate and consider the role of environmental conditions and driver behaviour, and the interaction between these three in any road safety analysis because crash rates are significantly different in geographical locations with similar road characteristics but different environmental conditions.

Some of the limitations of this research are: not considering the effect of some of road characteristics (e.g. lane and shoulder width, and overtaking zones), additional factors such as animals and alcohol, and type of crashes (e.g. run-off, rear end, or turning) because of the data limitation. In addition; Further research and some simulation studies are required to investigate the differences between male and female drivers and speed in day/night and eastbound/westbound.

More in-depth analysis of crash data, use a regression method to link all the variables, and implementing the method to new study areas are some of the future work that are required for validating of the results.

Acknowledgment

We need to acknowledge RMS for providing crash and traffic volume data, and departments of lands for providing road centreline data. It was not possible to do this research without their supports.

Table 1. Data Exploration: Kings Highway, 2007-2011

		Crash Freq.		Crash Rate	Driver Age (yrs.)		Driver Gender			T. Speed (Km/h)	
		N	**%**	**/100000 MV**	**Mean**	**SD**	**M**	**F**	**M/F**	**Mean**	**SD**
Total (24h.)		180	100.00	2.45	40	18	106	73	1.45	78.51	23.65
Day (12h.)		144	80.00	**2.31**	**42**	19	80	64	**1.25**	76.84	22.32
Night (12h.)		36	20.00	**3.25**	**33**	16	26	9	**2.88**	85.83	28.03
East	**Total (24h.)**	115	63.90	**3.13**	40	18	75	39	1.92	75.91	24.90
	Day (12h.)	93	51.67	**3.02**	**42**	18	60	33	1.82	74.44	23.65
	Night (12h.)	22	12.23	**3.68**	**31**	12	15	6	2.5	83.93	30.60
West	**Total (24h.)**	65	36.10	**1.77**	40	20	31	34	0.91	82.80	20.93
	Day (12h.)	51	28.33	**2.74**	41	19	20	31	**0.64**	81.22	19.16
	Night (12h.)	14	7.77	**1.77**	36	20	11	3	**3.66**	87.86	26.00

Figure 4. Crash Frequency distribution through Kings Highway: A comparison between Day and Night

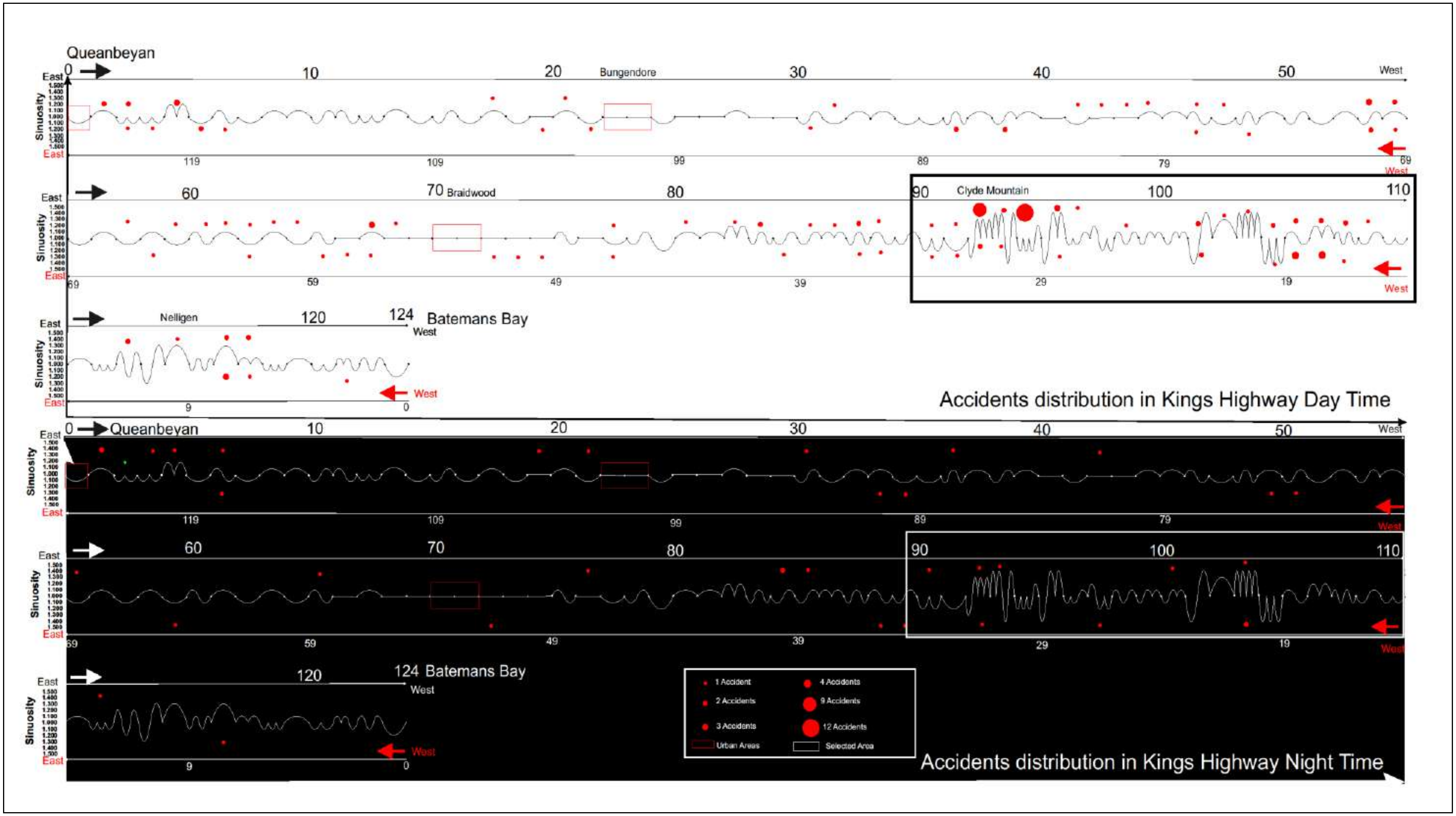


Figure 5. Correlation Matrix between Crash Rate and Road Geometry Factors: Day and Night Comparison

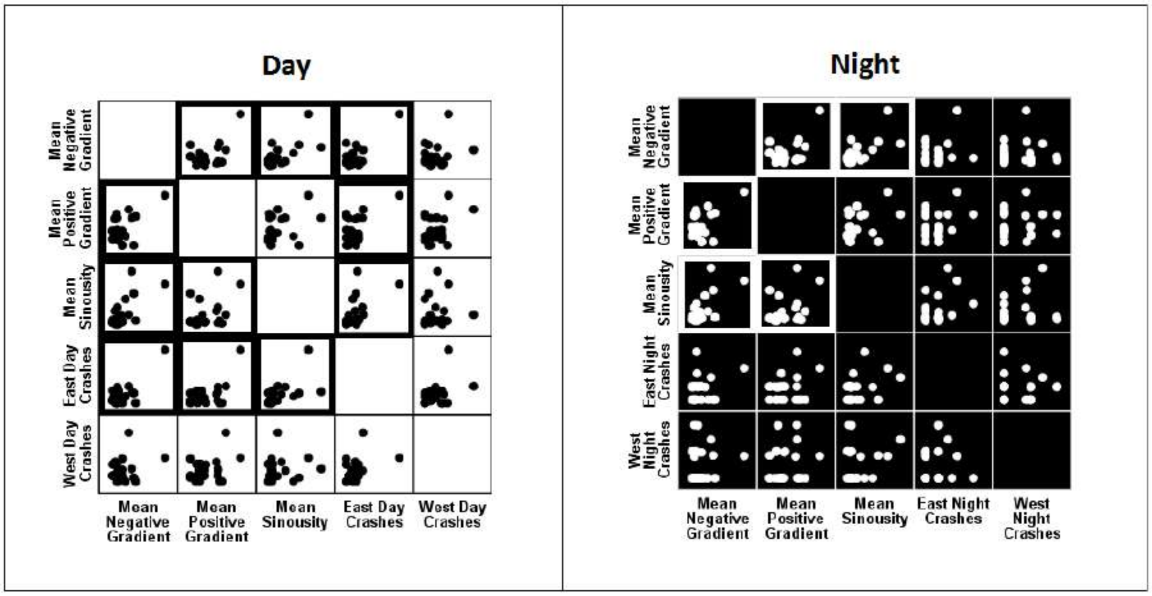
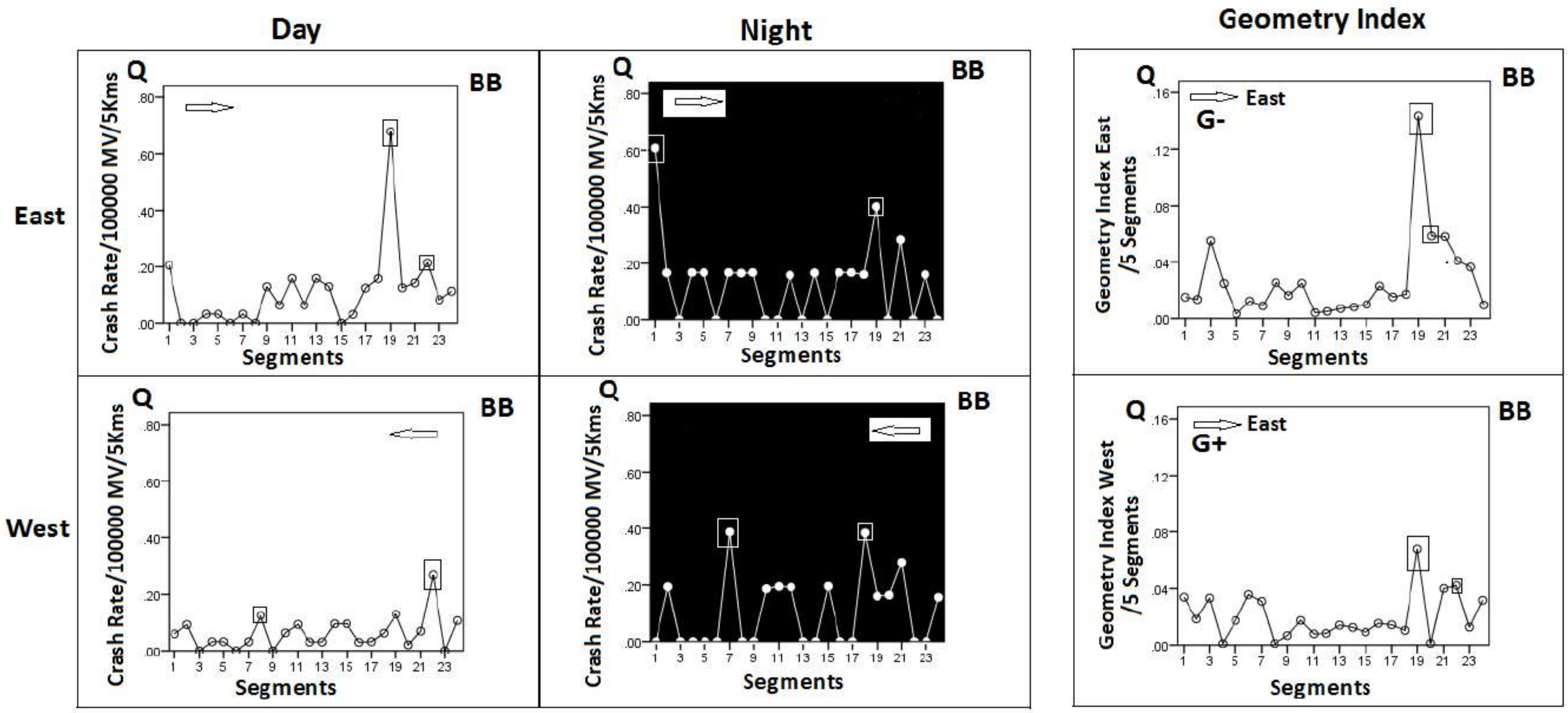


Figure 6. Summary of Crash Rate and Geometry Index distribution in Kings Highway



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The NZ Transport agency, teachers and educators design evidence-based road safety education in New Zealand schools

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Abstract

New Zealand's road safety strategy to 2020, Safer Journeys, has led to broadened design-led school-based road safety education. NZ Transport Agency curriculum resources, written by educators and secondary teachers, intentionally give effect to research for best practice teaching and learning. As a result, younger road users may gain the knowledge and dispositions needed to participate and contribute to a safe road system. The resource collection is based on educational theory and practice that finds learning to be contextual, actively constructed, and socially negotiated. There is a need for learning that promotes deeper understanding and builds personal and social agency. Building blocks for innovative learning included collaboration, community service, student inquiry and formative assessment. The NZ Transport Agency design process is future-orientated, scalable, agile and user-driven. The resources enable teachers to address their priorities across curriculum areas. Teachers can scaffold learning in which students relate to and extend road safety concepts situated within relevant personal and community contexts and within subject areas knowledge and skills. Customised sequences of learning experiences support students through opportunities to lead investigations and manage and participate in personal and community road safety outcomes. Interviews with teachers suggest they view curriculum-designed learning experiences in road safety as an authentic context connecting students to deeper notions of curriculum areas such as mathematics and drama et al. These immediate outcomes raise potential for young people to grow adaptive expertise as critical and informed citizens and road users with proactive models of how citizens contribute to harm reduction.

Introduction

New Zealand’s *Safer Journeys Action Plan 2011-2012* stated that “many young New Zealanders do not have access to quality road safety education, either at school or through professional driver training. This needs to be addressed” (Ministry of Transport, 2011, p. 20). In response, the NZ Transport Agency created teaching and learning resources based on evidence for effective learning. Curriculum resources for years 1-8 and years 9-13 are online for teachers to freely download, modify and use.
A mathematics and statistics teacher who wrote and trialled a NCEA L1 assessment resource published by the NZ Transport Agency found:

> Students are taking away from this statistics investigation road safety messages about the issue of cell phone use during driving and the impact of being tired on concentration levels. They haven’t been explicitly told these messages; instead they’ve looked at the evidence and formed meaning for themselves from the data (S Howell, personal communication, April 30, 2015).

This discussion will outline how careful design of resources is the vehicle for students to develop agency – the capability to both develop their knowledge of road safe behaviours and to act on that knowledge.

Effective school-based road safety education

Hakkert and Gitelman (2014) note that systemic approaches to road safety were not a consideration in the early years of motorisation. Today the Safe System approach presents young people with many entry points to unpack road safety in line with the moral, technical and social knowledge curation and creation that being a citizen sharing the roadway can entail.

The agency's curriculum resource design is underpinned by evidence of what works and doesn't work in schools. Influences include *Principles for School Road Safety Education: A Research Summary* (Government of Western Australia, 2009). It advises: embed road safety education programs within a curriculum, use student-centred interactive strategies, and help students influence peers as safe road users.

Another significant work is *Effective community & school based road safety for young people: a summary of the research* which calls for comprehensive curriculum programs that are interactive and focus on the social competency of the students (Harris, n.d.).

Chamberlain and Hook (2012) say curriculum designers need to provide activities deliberately linked to how young people learn, ensure relevance that motivates and engages young people, create dissonance and develop deep knowledge, and develop competencies for making decisions and taking action.

Why a socio-constructivist approach to learning?

Today, learning is often understood to be "shaped by the context in which it is situated, and is actively constructed through social negotiation with others" (Dumont, Istance, & Benavides, 2012, p. 3).

The Transport Agency's program reflects this theoretical base, and supports a nationwide shift in road safety education approaches from transfer of knowledge and skills, toward engaging students in socially-constructed learning. The aim is making new learning relevant for young road users so they deeply understand the complexity of both road safe behaviours and the capabilities of being a citizen in skilled and active ways, and who collaborate with community members to address safety issues (Chamberlain and Hook, 2012).

An implicit future focus arises through the need to build adaptive expertise – "the ability to apply meaningfully-learned knowledge and skills flexibly and creatively in different situations" (Dumont, Istance, & Benavides, 2012, p. 3). Participation in community advocacy requires students to develop agency, defined by Hayward as "a citizen's capacity for developing independent thought (will formation) and the capability for freely choosing to act on those ideas (volition) (Hayward, 2012, p. 64).

Road safety education in the classroom requires innovative learning environments, using 'building blocks' such as cooperative learning, service learning that engages students in authentic situations in their communities, formative assessment that helps the students and teacher understand their progress and plan next steps, and inquiry-based approaches (Dumont, Istance, & Benavides, 2012, p. 10).

Integration into effective pedagogy

Hipkins (2015) notes that the Transport Agency's integration of a road safety context within and across subject areas "is used to enlarge the learning in a way that deepens its purpose, making strong links to students' interests and concerns in the process". She writes that resultant learning "has the future-focused potential to have an ongoing impact on their lives, and the lives of others through how they contribute on many levels to societal problem-solving."

Resource design supports students to look at the discourses embedded in road use in their locations in terms of normative moral orders (Davies, 2011). The design provides the tools for teachers to make every-day normative actions more visible and support students to create new constructs of road user behaviours for critique.

The Transport Agency asked teachers, and educators who consult in schools, to write and trial the curriculum resources it publishes. The agency mandated to resource writers that concepts of road safety followed best practice methodologies. The process included engaging with user reference groups of teachers to generate ideas and review existing resources.
Example reference group responses:

> Resources that get past surface learning outcomes and prompt for deep learning based on the New Zealand Curriculum … open-ended opportunities to identify, explore and manage transport challenges facing local communities … editable resources that relate to a young adult's lived experiences in being a passenger, learning to drive, buying a car, getting pink stickered, learning the official NZ Road Code. (Hook, 2014, p. 7)

Each resource enables clear linkages to New Zealand Curriculum values, key competencies and achievement objectives across learning areas as diverse as physics, drama and visual arts. Self-assessment rubrics, exemplars and other content enable students and teachers to monitor and plan their learning.
The resources aim to provide students with agency and develop key competencies like *managing self* as they spiral through a progression into deeper learning (Biggs as cited in Hook, 2015). Teachers, students and the resources themselves enable this by mapping activities to SOLO Taxonomy, a model of learning that is used to develop levels of surface, deep and conceptual understanding (Biggs & Collis, 1982).
The breadth and flexibility in each resource is based on the principles of universal design for learning, that is, providing students with multiple means of representation, action and expression, and engagement (CAST, 2011).The result is unique learning experiences in each classroom.
A secondary maths teachers who adapted agency resource and data set for his year 13 students, found that:

> Students responded really well to the context. They took on board the stopping distance message and researched to find other factors that influence it … I took the data and the context in general and I married that with the demands of the curriculum and assessment at level 3 (NZ Transport Agency, 2013).

Ongoing review of student outcomes

Programme evaluation is real-time, influences the agency's next steps, and has led to published case studies. Phone and email interviews and school visits in the past five years gained qualitative information from at least 35 primary and secondary teachers using curriculum resources plus at least 20 others who took part in agency student competitions and storybook projects with a curriculum focus. Teachers gave access to a few student written and recorded verbal responses. Teachers were asked how they adapted the resources, what learning activities students completed, what helped students learn, characteristics of student engagement and student outcomes related to road safety. A sample of responses follows.
A teacher of year 3-4 class reported "there's that deeper learning – they are predicting. Takurangi writes 'in the future I want to see when you get tickets to the big event, they come with bright jackets so you can be seen by people'" (Ministry of Education, 2011).
An English teacher using NCEA L2 resource on close viewing of road safety ad campaigns:

> It's relevant; it's something they're interested in. They've got the basic skills in English for analysing the video and because they can relate to the target audience and the purpose of the text, they can relate to the assessment and the result is they show more understanding (NZ Transport Agency, 2015b).

Secondary science teachers:

> There are definitely more students that understand force and motion because we taught it this way … Science gives students the knowledge to make their own choices… We want our students to make decisions based on science and logic, rather than just remember rules (Ministry of Education, 2012).

A Year 9 student using an English resource aligned to the agency's Drive Social campaign wrote that "I enjoyed doing the persuasive letter because we could change and help improve our roads" (NZ Transport Agency, 2015a).
Year 13 visual arts student:

> I started researching the Legend campaign and the thinking behind it, and I looked at some statistics around youth drunk driving. What I wanted to convey was a focus on the sober driver… I started looking at this comic-book style idea and I've created a character now, who is Soberman and he is a hero (unpublished video, 2013).

These outcomes arise from participatory curriculum-based learning facilitated by teachers adapting agency resources. Each instance raises the opportunity for young people and their whānau to grow adaptive expertise as critical and informed citizens and road users with proactive models of how they can contribute to harm reduction.

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Motorcyclist collisions with roadside barrier motorcyclist protection systems

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Abstract

In Australia, around 12 motorcyclists per annum are fatally injured following a collision with a roadside barrier. With a goal of reducing such trauma, the Australian and New Zealand Road Safety Barrier Systems and Devices Standard (AS/NZS 3845.1:2014) recently introduced a crash test requirement for 'motorcyclist protection systems', intended to improve the safety of roadside barriers for motorcyclists. The crash test is based on the European CEN technical specification (CEN/TS 1317-8:2012). However, there are some limitations to such crash testing, including the biofidelity of the anthropomorphic test device (ATD) and the fact that only one collision orientation is tested.

The aim of the present study is to provide information regarding the effectiveness of motorcyclist protection systems under a variety of field-observed collision scenarios. Finite element simulations of a human body model sliding into a roadside barrier with a rub-rail system were undertaken. Two different impact orientations, three impact angles and four impact speeds were considered. It is shown that the injury potential of the W-beam barrier is substantially reduced with the rub-rail, where motorcyclist serious thoracic and head-neck injuries are likely prevented for most sliding collision orientations, except those at the highest angles and speeds. It is envisaged that the present simulation results will complement existing test data using ATDs, providing substantive information to regulators and road authorities confirming the large injury reduction potential of rub-rail systems, thereby promoting their installation and assisting in reducing trauma related to motorcyclist collisions with roadside barriers.

Introduction

In Australia, around 12 motorcyclists per annum are fatally injured following a collision with a roadside barrier (Bambach et al 2012). The Australian and New Zealand Road Safety Barrier Systems and Devices Standard AS/NZS 3845.1:2014 (2014) recently introduced a crash test requirement for devices intended to improve the safety of roadside barriers for motorcyclists, based on the European CEN technical specification CEN/TS 1317-8:2012 (2012). While this crash test protocol has been demonstrated to be a robust procedure, with many crash tests performed in Europe, there are some limitations (typical to crash testing) (Grzebieta et al 2013): only one impact trajectory is tested (head-leading at 30° and 60 km/h); the head-leading orientation does not consider direct chest impacts and associated injuries; and the crash test uses a Hybrid III anthropomorphic test device (ATD), which has proven biofidelity, however does have limitations (particularly under vertical head-neck axis loading and side impacts to the thorax in the coronal plane).

Recent motorcyclist-barrier crash studies (Bambach et al 2012, Bambach et al 2013, Grzebieta et al 2013) have indicated that: the most frequent crash type was a collision with a steel W-beam barrier (guardrail) of which half are in the sliding posture (i.e. the motorcyclist is separated from the motorcycle) and half remain seated in the upright posture; impact angles varied between 5° and 33°, with a mean of 15.4°; impact speeds varied between 60 and 200 km/h, with a mean of 101 km/h; and the most frequently occurring serious injuries were thoracic injuries, followed by head and lower extremity injuries.

Considering the limitations of crash testing, a human body Finite Element model was used to assess human kinematics and injury potential for a wide range of sliding impact configurations, thereby assessing devices for a full range of field-observed collision modes. Devices considered were fixed to steel W-beam barriers. This paper provides a summary of the findings.

Methods

The device selected for this study is a public domain rub-rail system manufactured and sold in Australia and installed on steel W-beam barriers. Many kilometres of this device has been installed in New South Wales, Victoria, Queensland and South Australia. The rail consists of a flat steel surface with tapered edges, and is bolted to the face of the blockout via a steel plate connector (Figure 1a). A finite element (FE) model was generated from engineering drawings of the device (Figure 1b). Two interior bays of a W-beam barrier were modelled (Figure 1c).

The Total Human Model for Safety (THUMS) average size male human body model was used to simulate the motorcyclist in this study, developed by Toyota Motor Corporation. The FE mesh consists of nearly 2,000,000 elements representing the components of the human body, and the response to dynamic loads has been shown to be within acceptable biomechanical limits (Bambach and Grzebieta 2013, Iwamoto 2002). The collision orientations of THUMS with the W-beam barrier were based on the CEN crash test orientation and the Australian crash data impact orientations discussed in the Introduction, including orientations of head-leading and chest-leading, impact angles of 15°, 30° and 45°, and speeds of 20, 40, 60, 80 and 100 km/h (Figure 2). The latter orientation was selected to create a direct chest impact in order to assess thoracic injury potential.

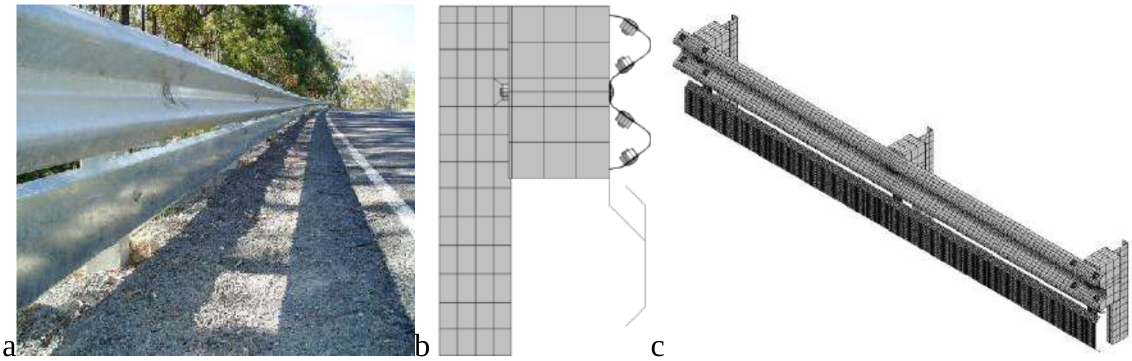

Figure 1. a) Australian rub-rail device, b) FE model of the rub-rail and W-beam barrier, c) isometric view of the rub-rail and barrier

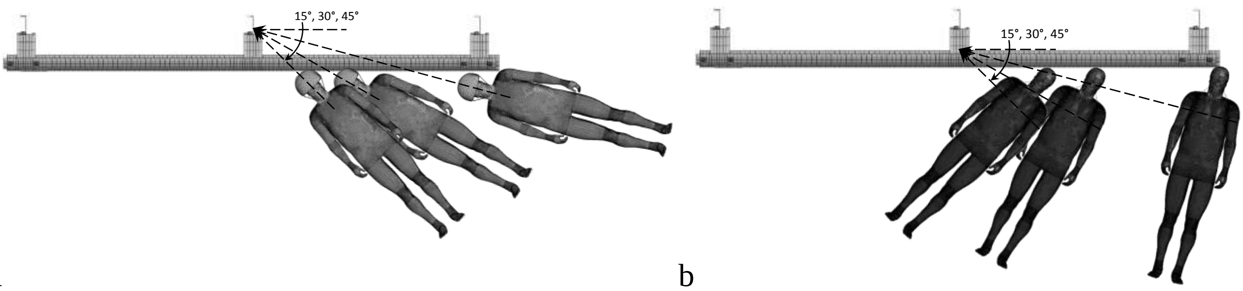

Figure 2. a) Head-leading orientations, b) Chest-leading orientations

Results

The results of the collisions in the head-leading orientation are summarised in Tables 1 and 2. Cervical vertebral fractures (fx, AIS 2+) were assessed using a plastic strain to fracture in the cortical bone of 3%. Brain injury was assessed using the Cumulative Strain Damage Measure (CSDM), where threshold strains of 10%, 15% and 30% were used to indicate mild traumatic brain injury (MTBI, AIS 2), diffuse axonal injury (DAI, AIS 4) and severe brain injury (SBI, AIS 5+), respectively. Serious head/neck injuries were predicted to occur around 20 – 40 km/h for unprotected W-beam posts, 80 – 100 km/h for the rub-rail impact at 30°, and 60 – 80 km/h for the rub-rail impact at 45°. Injuries were not predicted for the rub-rail impact at 15° for all speeds.

The results of the collisions in the chest-leading orientation are summarised in Figure 3. Thoracic injury was assessed using the normalised chest compression, being the maximum rib deflection divided by the original width of the chest. Values of 0.383 and 0.496 were used to indicate threshold values between moderate (AIS 1,2), serious (AIS 3,4) and critical (AIS 5+) injury (derived from cadaveric studies of chest injury, Viano et al 1989). Serious thoracic injuries were found to occur at around 30 km/h for unprotected W-beam posts, and were found to not occur for rub-rail impacts at all angles and speeds.

Table 1. Brain injuries simulated with THUMS in the head-leading orientation

	Impact angle	**20 km/h**	**40 km/h**	**60 km/h**	**80 km/h**	**100 km/h**
Unprotected post	15°	MTBI	MTBI	*Not modelled*		
Rub-rail	15°					
Rub-rail	30°			MTBI	DAI	DAI
Rub-rail	45°		MTBI	DAI	SBI	*Not modelled*

Note: Blank cell indicates no injury unless stated otherwise.

Table 2. Cervical spine injuries simulated with THUMS in the head-leading orientation

	Impact angle	**20 km/h**	**40 km/h**	**60 km/h**	**80 km/h**	**100 km/h**
Unprotected post	15°	3 fx	4 fx	*Not modelled*		
Rub-rail	15°					
Rub-rail	30°					2 fx
Rub-rail	45°			1 fx	6 fx	*Not modelled*

Note: Blank cell indicates no injury unless stated otherwise, fx = cervical vertebral fracture

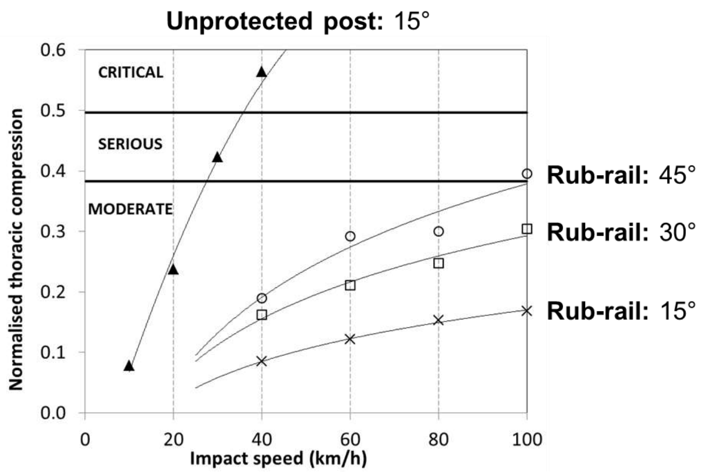

Figure 3. Chest injuries simulated with THUMS in the chest-leading orientation

Conclusions

Collisions with unprotected W-beam posts present a severe injury potential for a sliding motorcyclist, even at relatively low speeds. The Australian rub-rail device successfully redirected the motorcyclist and prevented a post impact, thereby greatly reducing the injury potential. This study found that the rub-rail will likely prevent serious thoracic injury at all practical impact angles and speeds, and likely prevent serious head/neck injury at low impact angles and higher impact angles at low speeds. However, the potential for severe head/neck injury exists at high angles and high speeds.

While European crash tests with ATDs have demonstrated that rub-rails prevent serious injury for head-leading sliding collisions at 30° and 60 km/h, this study compliments these results, and demonstrates the substantial injury reduction potential of rub-rail devices for a wide range of other collision orientations observed in the field.

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Learner Driver Mentor Programs: Stakeholder perspectives on an ideal program

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Abstract

This study investigated the development and operation of Learner Driver Mentor Programs (LDMPs). LDMPs are used throughout Australia to assist young learner drivers to gain supervised on-road driving experience through coordinated access to vehicles and supervisors. There is a significant lack of research regarding these programs. In this study, 41 stakeholders including representatives from existing or ceased LDMPs as well as representatives of other groups completed a questionnaire in either survey or interview format. The questionnaire sought information about the objectives of LDMPs, any social problems that were targeted as well as the characteristics of an ideal program and what could be done to improve them. Stakeholders indicated that LDMPs were targeted at local communities and, therefore, there should be a clear local need for the program as well as community ownership and involvement in the program. Additionally, the program needed to be accessible and provide clear positive outcomes for mentees. The most common suggestion to improve LDMPs related to the provision of greater funding and sponsorship, particularly in relation to the vehicles used within the programs. LDMPs appear to have an important role in facilitating young learner drivers to acquire the appropriate number of supervised hours of driving practice. However, while a number of factors appear related to a successful program, the program must remain flexible and suitable for its local community. There is a clear need to complete evaluations of existing programs to ensure that future LDMPs and modifications to existing programs are evidence-based.

Introduction

Young drivers have a disproportionately high rate of involvement in road crashes (Bates, Davey, Watson, King, & Armstrong, 2014; McCartt, Shabanova, & Leaf, 2003). Driving behaviours such as carrying peer passengers (Lam, Norton, Woodward, Connor, & Ameratunga, 2003; Preusser, Ferguson, & Williams, 1998), using their mobile phones (Gauld, Lewis, & White, 2014; McCartt, Hellinga, & Braitman, 2006), being under the influence of alcohol or drugs (Bates, Davey, et al., 2014) and driving at night (Fell, Todd, & Voas, 2011) increase crash risk for this group. As well as their behaviours, young drivers crash risk is increased because their ability to perceive hazards and assess various driving situations is still developing (Bates, Davey, et al., 2014), and they are distracted more easily (Buckley, Chapman, & Sheehan, 2014).

One countermeasure that is effective in reducing crash rates for young drivers is graduated driver licensing (Bates, Allen, et al., 2014). Graduated driver licensing schemes frequently have three phases: learner, provisional and open (Bates, Allen, et al., 2014). The learner phase enables new drivers to obtain driving practice while under the supervision of a more experienced driver (Bates, Watson, & King, 2014). The crash rates for drivers in the learner phase are low (Williams, 2003). The provisional phase enables newly licensed individuals to drive a car by themselves. However, they generally need to adhere to restrictions placed on them. These restrictions vary from jurisdiction to jurisdiction but include a minimum age they can obtain their licence, limits on the number of peer passengers able to be in the vehicle with the driver and night time driving restrictions (Bates, Darvell, & Watson, in press). Crash rates for novice drivers are highest in the first few months of driving on a provisional licence before they begin to decline (Williams, 2003). An open licence enables a person to drive on a full, unrestricted, licence (Masten, Chapman, Atkinson, & Browning, 2014).

Within Australia, a frequent requirement of the learner phase is that drivers complete an extensive amount of practice. The exact amounts vary amongst the states with 100 hours required in Queensland, 120 hours in New South Wales and Victoria (Senserrick, 2009) and 50 hours in Western Australia (Department of Transport, 2015). Compared to other places, such as the United States of America, these practice requirements are high. In the United States of America, the hours of practice requirement varies with some states not requiring any, and up to 70 hours are required in Maine (Insurance Institute for Highway Safety, 2015).

Supervised driving practice is important because research suggests that it may help to reduce crashes after the person starts driving by themselves on a provisional licence. However, the exact number of hours required to reduce driving risk is inconclusive (Steadman, Bush, Thygerson, & Barnes, 2014). In one study, learner drivers who made use of a longer learner period experienced about a 40 per cent reduction in crash risk compared with learner drivers who did not. The longer learner period resulted in learners obtaining more supervised practice. Learners who did make use of the longer permit period accumulated on average, 118 hours of supervised practice. Learners who did not make use of the longer permit period accrued, on average, 41 or 47 hours of practice (Gregersen et al., 2000).

Parents play an important role within graduated driver licensing systems (Brookland, Begg, Langley, & Ameratunga, 2014; Williams, Leaf, Simons-Morton, & Hartos, 2006). It appears that parents are the primary providers of supervised hours of practice, although additional people such as siblings or other family also provide supervised practice to learner drivers (Bates, Watson, et al., 2014; Jacobsohn, Garcia-Espana, Durbin, Erkoboni, & Winston, 2012). Mothers appear to provide a greater number of hours of supervised practice than fathers (Bates, Watson, & King, 2013). However, sometimes it is difficult for a learner to access a parent to be their supervisor for reasons such as no longer living at home (Scott-Parker, 2015). Given this situation, individuals without access to a private supervisor such as a parent are placed at an inherent disadvantage in obtaining the required amount of supervised driving practice.

Learner Driver Mentor Programs (LDMPs) are one intervention that can be used to address this inequity. LDMPs can increase the equity of admission to the licensing system by providing access to appropriate supervisors and/or vehicles and thus assisting in achieving the necessary supervised driving hours. LDMPs are initiatives that provide learner drivers who face significant difficulties in obtaining the required on-road supervised driving experience the opportunity to access a suitable vehicle and supervisor. These supervisors, referred to as mentors, are typically volunteers, while the vehicle used is typically a dedicated program vehicle obtained through funding or sponsorship, although some LDMPs may utilise the mentor’s own vehicle.

LDMPs are not designed to provide formal instruction, but rather provide learners the opportunity to practice driving in a suitable vehicle in order to assist them in meeting the required number of hours of supervision in the requisite types of conditions. LDMPS vary in terms of their objectives, structure and the number of driving hours that are provided. LDMPs are often nested within community-based programs, which may have a broader range of objectives such as improving employment and/or education opportunities, social engagement and young driver road safety. There has been little formal research undertaken regarding LDMPs. Stakeholders provide an important assessment of operations by providing ‘on the ground’ understanding of the way in which an LDMP can be and has been implemented.

Method

This study involved consultations with different types of stakeholders including individuals involved with both existing LDMPs and those that were attached to LDMPs that no longer operate, government organisations with a vested interest in youth safety and/or road safety, insurance companies and workplace training corporations. Participants came from Victoria, Queensland, Western Australia, Tasmania, New South Wales and the Northern Territory. Additionally, some participants represented national stakeholders. No socio-demographic data regarding age, gender, was collected. Different versions of the questionnaire were developed for each group of stakeholders.

The questionnaires sought information about a range of topics including:

- Particulars regarding the program including name, location, the year it commenced
- Program objectives
- Staffing
- Stakeholders involved with the program (including roles and existence of a steering committee or advisory group)
- Mentors and mentees including information about recruiting, training and induction
- Funding including the sources and adequacy
- Barriers and difficulties faced and how these were managed
- Evaluations including planned evaluations
- Perceived strengths and weaknesses of the program
- Perceived characteristics of an ideal LDMP

Participants were provided with the opportunity to complete the questionnaire in writing (sent via email) or via telephone. Stakeholders who were based in south-east Queensland, close to the research team based at the Centre for Accident Research and Road Safety – Queensland at the Queensland University of Technology, had the option of completing the questionnaire in a face-to-face meeting. Interviews that were conducted face-to-face or over the phone ranged from approximately 30 minutes to 90 minutes. The various options available for completing the questionnaire did not appear to affect the participation rates. All consultations were confidential and undertaken individually. When a stakeholder provided written consent to do so, face-to-face and telephone consultations were audio-recorded to enable transcription. Most stakeholders took the option of completing the questionnaire in writing and returning it via email as it gave them more freedom regarding when they could respond.

A manual content analysis of the responses from the stakeholder consultation phase of the project was conducted by a member of the research team to ensure consistency of analysis. The analysis identified major themes related to each of the key topic areas investigated as part of the questionnaire. Emerging themes falling outside these intended topics were also analysed where relevant.

Results and discussion

Within this study, 41 stakeholder consultations occurred with 33 of these with individuals who were directly involved with existing or ceased LDMPs. Of the remaining eight stakeholder consultations, five were conducted with government organisations, two with insurance companies and one with a corporation focused on workplace training.

Many of the programs best known to participants (e.g. the one's that they had worked on) sought to address social inequity issues associated with the compulsory requirement to acquire a specific number of driving hours on a learner licence and to help mentees overcome social and economic disadvantages associated with not having a driving licence as well as improving road safety outcomes and social connectedness.

Stakeholders were asked about their perceptions of the strengths and weaknesses of their programs, as well as the perceived characteristics of an ideal LDMP. Stakeholders discussed several elements that they associated with a successful program LDMP.

Local focus

Stakeholders directly associated with LDMPs highlighted the importance of a program that addresses a local need, their advice for developing or newly implementing a program would be to best understand the community need. This research suggested that the most appropriate way to do so was to undertake extensive community consultation prior to the program's implementation. Given that LDMPs typically represent community development programs, it was argued that programs should establish cooperative and supportive relationships with the community.

> *We're reliant on local people being committed and contributing in ways that they can… ….it's the collective of people having a shared goal to try and help young people who are disadvantaged get a licence….*(stakeholder directly associated with an LDMP)

In addition, the common requirement to raise additional funds through sponsorship and donation was argued to encourage a sense of community ownership of the program, particularly in more remote communities. It was also suggested that programs should be readily accessible, including ensuring adequate public awareness of the program and making the process of participating in the program as straightforward as possible with some participants noting a number of bureaucratic requirements were restrictive.

One stakeholder did suggest that for some programs targeted at remote communities, community ownership and involvement in the program is critical for its success. In these type of cases, the stakeholder suggested that the role of the government should be restricted to educating stakeholders and the public about the rationale behind the program and the requirement for policies and legislation. Examples provided included education about the graduated driver licensing system, helping to identify and implement ways to recruit and reward mentors and facilitating process to ensure community organisations are unimpeded from becoming involved with LDMPs.

Flexibility

Further reflective of understanding community need, stakeholders directly associated with LDMPs noted that flexibility was crucial to allow the program to be responsive to the specific needs of each community. They noted a general structure on which their program was based recognised that communities and individual mentors, students and each relationship had different needs. That is, program coordinators were often perceived as having considerable autonomy in the way that they performed their role, even though the program content itself might be quite structured. This was argued to be particularly important in relation to programs delivered on a state-wide basis.

Flexibility was also highlighted as important by other stakeholders involved in the consultation. They indicated that while it was important to have a basic, systemic structure regarding how the fundamental characteristics of the program are operated (e.g., vehicle booking systems, consistent mentor training), it was also argued that there needs to be enough flexibility for the program to adapt to the specific needs of each community (e.g., how mentors are trained, recruitment strategies). As part of the basic, systematic structure of the program, stakeholders suggested that consistent policies and procedures should be developed and documented in relation to various aspects of the program, including recruitment of learner drivers and mentors, mentor training, risk management and vehicle booking systems. To more effectively cater for culturally diverse mentees, stakeholders also indicated that it was important to establish a network of culturally diverse volunteers who are appropriately trained (e.g., cultural sensitivity). It is also important to have an induction process which clearly outlines codes of conduct and important policies and procedures.

Funding and costs

A number of stakeholders involved with LDMPs spoke from experience as they reported the importance of careful and realistic considerations during the development of any LDMP. Specifically, a common factor argued to be important was having a realistic understanding of the costs associated with the program, and developing a budget accordingly. It was argued that program developers should engage in discussions with other programs to ensure they consider all budgetary concerns and avoid being conservative in estimations of costs. Following on from this factor, it was also argued that program developers need to have a realistic understanding of program capacity to ensure it is not exceeded (i.e., take on more learners than the program can accommodate). Indeed, a number of stakeholders suggested that program efficiency and effectiveness should not be jeopardised in the name of increasing program capacity. In addition, it was suggested that program developers must have an adequate understanding of the legislative issues associated with program operation, including insurance, and take the appropriate steps to reduce liability and manage risks. Some participants believed that it was the role of corporate partners to provide assistance with this.

Increased base, or recurring, funding was by far the most commonly suggested way to improve the operation of a program. Indeed, increased base funding was argued to be crucial, not only to improving program efficiency and effectiveness through the provision of more resources, but also in regards to allowing for program expansion for the purposes of meeting increasing demand. It was typically argued that adequate funding allowed programs to maximise their capacity and reduce the pressure on program staff to acquire additional funds and sponsorship. Stakeholders suggested that the focus should be on securing ongoing and sustainable funding, as opposed to the relatively short funding periods programs are typically currently subjected to.

> *…driving programs like this fall between the [funding] cracks because we don’t seem to be anybody’s [responsibility].* (stakeholder directly associated an LDMP)

> *…in the end you need to have sustainable funding…it’s important to have it [the program] delivered at a community level because they’re the people who have access to the mentors and connected with the clients.* (industry/government stakeholder)

In addition, it was suggested that there was an increased need for greater assistance in the acquisition of additional funding, sponsorship and in-kind support from the government, community and local industry. It is possible that the inclusion of research evidence regarding the effectiveness of LDMPs could be used to support requests for further funding.

A number of stakeholders who were not directly associated with LDMPs noted the importance of having a well-developed business plan that focussed on sustainability of funding. Specifically, it was argued that programs should establish strong corporate partnerships for sourcing vehicles and other resources, as well as sponsorships and donations from local businesses. In addition, stakeholders highlighted the need for effective marketing strategies as a method for enticing local businesses and funding bodies to become involved in the program.

Staffing

Almost universally, having a dedicated and enthusiastic program coordinator responsible for the day-to-day operation of the LDMP was argued to be critical to program efficiency and success. It was suggested that the individual performing this role must be given ample time and money to perform their duties, as well as considerable autonomy in the manner in which they operate the program. Having other dedicated program staff with strong administration and people management skills, where necessary, was also perceived as being important for program efficiency.

Mentors

The recruitment of quality mentors (e.g., committed, supportive, safety conscious) who meet minimum standards was also reported as being fundamental to the sustainability and effectiveness of a program. While the actual process of recruitment will vary between organisations, it could include consulting with groups and organisations within the community that have a vested interest in youth safety, advertising through the media, conducting presentations at relevant community events, promoting the program through key partners and relevant stakeholders as well as advertising on the program vehicles. The requirement to recruit a greater number of female mentors was perceived as being particularly important. This was because many girls do not feel comfortable or, in some cases, that it is culturally appropriate for them to have a male mentor. Additionally, stakeholders believe that it is significant to have mentors that suit the ethnic diversity of mentees involved in the program. Moreover, a number of stakeholders argued that programs need to ensure they have flexible training options for mentors (e.g., online training) that reduce the lag time between mentor recruitment and mentor involvement in the program. Additional professional development opportunities for mentors (e.g., conference attendance, guest speakers, short courses) were also argued to be important for ensuring mentors are efficient in their role and that they benefit from their experience in the program as well. Mechanisms to monitor mentors could include conducting regular group debrief sessions with the mentors and mentees to provide an opportunity to provide feedback and ask questions as well as being proactive in approaching mentors and mentees for brief discussions.

Given the perceived importance of mentors, it was argued that they must be provided with a high level of support from program staff and should receive greater recognition and reward for their hard work and dedication to the program (e.g., recognition events, milestone gifts). It was suggested that this would increase their perception of being appreciated, which would subsequently enhance retention rates. In addition, it was strongly suggested that the role of volunteer mentors should be publicly recognised on a regular basis, through such avenues as media recognition and award ceremonies. It was argued that this recognition would ensure mentor satisfaction and enhance retention rates. However, stakeholders acknowledged that in some cases it was difficult to reward mentors.

> *..because they are voluntary, it can be difficult to reward them….just under different legislation about what volunteers roles are….you can't be paying for instruction so to speak*. (industry/government stakeholder)

Manuals

The development of operations manuals that clearly define program policies and procedures was argued as critical in ensuring program efficiency and the achievement of program objectives. The manuals could include, but not limited to, information such as the rights and responsibilities of the learner drivers and the mentors, policies regarding the use of the program vehicle, matching procedures, mentor training and grievance and complaints policies.

It was argued that programs must have positive outcomes for the target audience. At a minimum, it was suggested that programs should assist learner drivers who have difficulties in complying with requirements of the GDL legislation (e.g., minimum hours) with the opportunity to obtain their licence by providing access to a suitable vehicle and supervisor. In addition, it was argued that programs should strive to provide driving practice, road safety knowledge and attitudes, social equality and access to other programs and services, community and family connectedness, while also providing a positive role model, opportunities for personal growth and the acquisition of fundamental life skills. However, it is possible that a LDMP that emphases too many goals may lose focus.

Networks

To facilitate evidence-based program development and efficient program operation, many stakeholders reported that it is crucial to establish strong networks with other similar programs and encourage the sharing of information, experiences and resources. Cooperative and supportive relationships between key stakeholders involved with LDMPs were perceived by many as crucial to enhancing program efficiency, reducing the likelihood of avoidable mistakes, fostering improvement in operations and program expansion.

> *Obviously a lot of us [co-ordinators] support each other. I pick their brains and they pick my brains….* (stakeholder directly associated with an LDMP)

At a broader level, the sharing of knowledge and experience regarding program management, as well as the sharing of program resources, with other similar programs, having a supportive steering committee or advisory group, and adopting a cooperative, whole of government approach to further encourage the sharing of resources, experience and knowledge, were all perceived to improve the effectiveness of a program.

Centralisation

Among stakeholders who operated programs at the state-wide level, there were consistent calls for a centralised approach to promotion and advertising. Suggestions included a centralised website that could be used as a hub to direct interested parties to their local program, as well as a centralised advertising campaign for newspapers, radio and television.

> *….every program was working in isolation effectively. There was no centralised promotion….we were all having to run our own show.* (stakeholder directly associated with an LDMP)

Stakeholders who were not associated with a current LDMP, typically perceived centralised management as being an important characteristic of an effective and efficient LDMP. Specifically, they argued that one organisation should generally be responsible for the broad management of the program, while community organisations or local councils should manage the delivery and operation of the program. It was argued that following this formula would facilitate community ownership and involvement in the program. It was suggested that, ideally, the community organisation responsible for program delivery would work closely with other youth organisations in the community, and that key influential organisations (e.g., local service clubs, Police, transport authority) would also be involved in the governance structure of the program, such as through the development of a steering committee or advisory group. Following on from this recommendation to have a local service provider with strong links within the community, a number of stakeholders highlighted the importance of conducting extensive community consultation prior to program implementation. It was argued that such a process would demonstrate a local need for the program, ensure the program reflects the interests of the entire community and would subsequently facilitate a sense of community ownership of the program.

Government and industry

Stakeholders who were associated with LDMPS were specifically asked how they believed government and industry could assist in the improvement of LDMPs, including their development, implementation and management. Overall, the most common suggestion was in relation to the provision of greater program funding and sponsorship, particularly in relation to program vehicles. More specifically, while there is government support available to some LDMPs, these stakeholders believed that they could provide greater support including more funding and sponsorship, assist in the brokering of partnerships with industry partners, provide information sessions for learner drivers and potential volunteers, assist with in-kind support such as the use of fleet vehicles or staff volunteering schemes, develop mentor training packages and assist in the promotion of state-wide LDMPs.

Stakeholders associated with LDMPs suggested that industry could provide additional funding, particularly for vehicles as well as sponsorship or in-kind assistance in the form of vehicles, maintenance and professional driving lessons and corporate volunteering schemes to assist with mentor recruitment.

> *…the corporate sector could make the donation of a car or money. That would be an enormous help….corporate volunteering would be a help.* (stakeholder directly associated with an LDMP)

The stakeholders suggested that it may be best to approach relevant organisations that stand to benefit from the positive outcomes of LDMPs such as employment agencies, car dealerships, mechanics, driving schools and other community-based organisations. The stakeholders suggested that research institutions could assist with program evaluations and the development of best practice guidelines while insurance companies could assist with discounts on insurance policies.

Conclusion

Overall, this qualitative study further develops our understanding of existing LDMPs and provides some suggestions for further improvements of these programs. Ensuring that programs maintain a local focus was a key theme emerging from the research. While the stakeholders highlighted some services that may be beneficial if centralised or shared such as promotion and advertising, a key idea was the ability to maintain the flexibility to allow programs to be focussed on the local area and issues. Funding was also highlighted as an area that could be improved. Many programs exist on non-recurring sources of funding. By developing a source of funding that was more secure, participants felt that the LDMPs could be improved. Participants also believed it was important to have a dedicated co-ordinator for the LDMP and high quality mentors.

One of the outcomes of this research was the development guidelines, including a checklist, for LDMPs (Soole, Reveruzzi, Bates, & Watson, 2014). These guidelines list 36 essential requirements of LDMPs in the areas of pre-development (e.g. identify the target audience and their unique needs), development (e.g. develop a comprehensive and realistic budget), operation (e.g. maintain a vehicle maintenance schedule) and evaluation (e.g. conduct a program evaluation). The use of these guidelines by groups and organisations that are interested in creating or amending a LDMP is recommended.

There are limitations relating to this research. As it is likely that LDMPs differ greatly in both the context in which they are located and the way that they are delivered, it is not possible to generalise the findings of this study to all LDMPs in operation throughout Australia. While this study has been useful in exploring how LDMPs operate, further research is essential to develop our understanding of the successful elements within LDMPs that support the development, operation and sustainability of the programs that evidence effectiveness in implementation. The research should include process and outcome evaluations of specific LDMPS in order to identify their effectiveness in reaching their goals. Additionally, they should identify the elements which support the development, operation and sustainability of the programs. Such research should consider whether particular disadvantaged groups differ in their experience of program models and consider effectiveness evaluations according to the target audience of the program. For example, if the target audience is diverse then all perspectives should be considered. Similarly, research is needed to evaluate whether LDMPs are more or less effective when they are combined with complementary education components. Given the efficacy of driving practice on safety, including through the learner phase, there is considerable research needed to best understand how to effectively and efficiently provide support to young people who do not have someone in their lives to provide supervised practice.

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Returning motorcycle rider refresher training in South Australia

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Abstract

On average around 15 motorcyclists die and 140 are seriously injured on South Australian roads each year. There were also 376 minor injury crashes involving a motorcycle on average per year over the 5 year period, 2010-2014. Motorcyclists have become a larger part of serious road casualties trending upwards from 11% in 2005 to 17% in 2014 whilst motorcycles have accounted for just above 3% of all registered vehicles during this time.

Older riders (aged 45+) are accounting for an increasing proportion of motorcyclist crashes. Analysis of motorcyclist serious casualty data was undertaken to determine who were likely to be returning riders. That is; riders aged 45 years or over at the time of the crash, who had held a motorcycle licence longer than 10 years and had returned to riding in the past 6 months, after not having a motorcycle registered to them for at least 5 years prior to the crash.

Data analysis indicates that around one rider fatality, 13 rider serious injuries and around 28 rider minor injuries on average per year may have been a returning/returned rider. It is possible that some of these casualty crashes could have been avoided if the riders involved had undertaken a riding skill refresher training course.

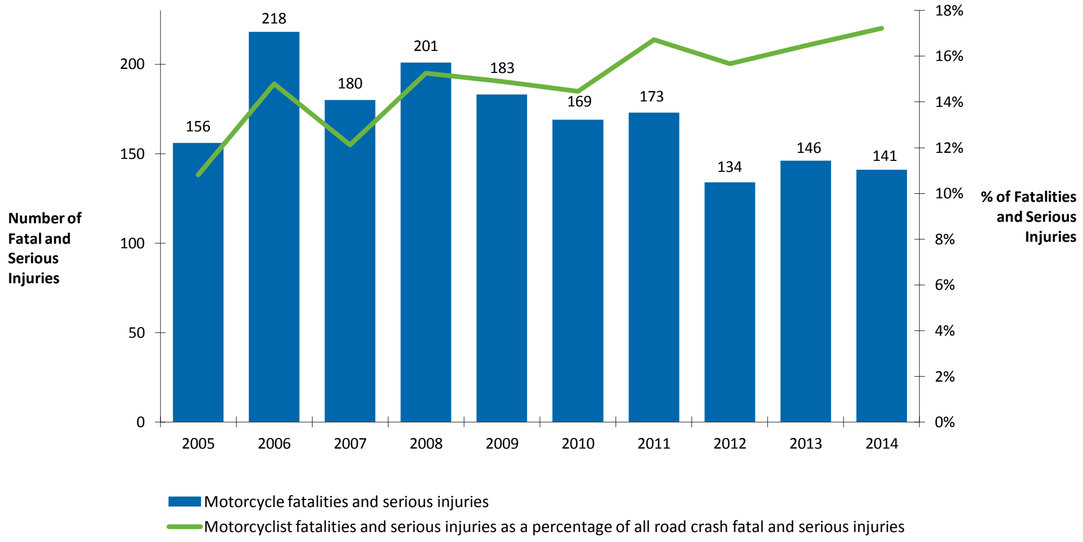
South Australia's Road Safety Action Plan 2013-2016 contains a priority to encourage returning riders to undertake a motorcycle skills refresher training course. The Rider Safe Returning Rider Course has been developed as a tailored program that will allow participants to practice the riding skills, knowledge and techniques to potentially reduce their road crash risk. The course is designed to teach / refresh riding skills, techniques and awareness for licensed riders and following a public communication campaign, and targeted mail out to returning riders, operational training courses are planned to commence in September 2015.

Introduction

The use of motorcycles has been increasing in recent years and research has found that, per distance travelled, the Australian rate of motorcyclist deaths is approximately 30 times the rate for car occupants, while the serious injury rate for motorcyclists is 41 times the rate for car occupants (DITRDLG, 2008).

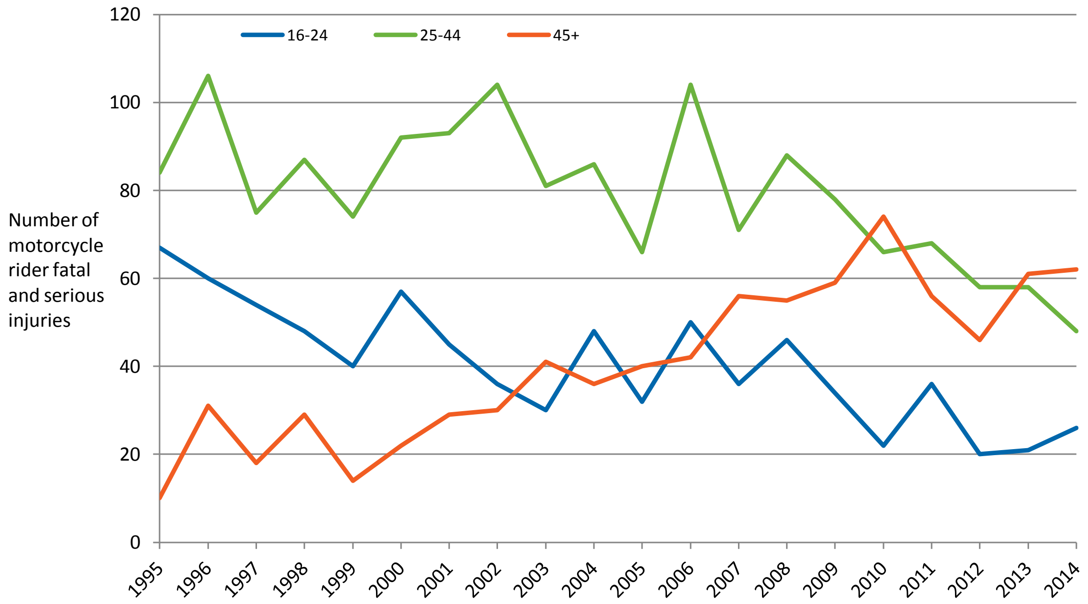
The incidence of motorcycle death and serious injury has increased in South Australia as a proportion of all road deaths, while other road user trauma has generally decreased. Figure 1 shows the number of motorcycle riders and pillion passengers killed or seriously injured on South Australian roads each year since 2005. It also shows the number of motorcyclists killed or seriously injured as a proportion of all serious road casualties. Even though the number of motorcyclist serious casualties has shown a downward trend, each year motorcyclists have become a larger part of road serious casualties trending upwards from around 11% in 2005 of all serious casualties to 17% in 2014.

Figure 1 –Motorcycle and pillion passenger fatalities and serious injuries as a percentage of all road crash fatal and serious injuries, South Australia, 2005-2014



In 2014, 45% (62 out of 138) of South Australian motorcycle rider serious casualties were aged 45 years or over as indicated in Figure 2.

Figure 2: Motorcycle rider serious casualties by age, South Australia, 1995-2014



The increasing trend in motorcycle serious casualties for riders aged 45+ in South Australia is in contrast to the decreasing trend in motorcycle serious casualties for younger motorcyclist age groups during this time. This is likely to be a result of both an increase in the general population of people aged 45 years and above and an increase in the usage of motorcycle in this age group (CASR, 2010).

A report on motorcycle crash trends over time by the Centre for Automotive Safety Research (CASR, 2010) outlines the findings from an analysis of 15,370 motorcycle crashes in South Australia for the period from 1990 to 2009. The CASR study found an increase in crash frequency for the older age group (40+ years) for all types of crashes during this period whilst the number of crashes involving younger riders had generally shown a decreasing trend. The CASR analysis found a much higher frequency in high speed non-metropolitan, and single vehicle crashes for the older age group which is indicative of a tendency toward more recreational riding and may also be attributed to an increase in returning riders.

Discussion

For the ten years from 1995 to 2004, there were on average 26 motorcycle riders aged 45+ killed or seriously injured. This number more than doubled in the ten years from 2005 to 2014 when there were on average 55 motorcycle rider serious casualties per year aged 45+. This represents an 85 per cent increase. Over this same 10 year period South Australian motorcycle registrations have increased by around 50 per cent so older rider serious casualties have increased by around 35 per cent more than motorcycle registrations during this time. It is likely that some of these serious casualties involving people aged 45+ were returning riders.

There are approximately 51,000 registered motorcycles and around 170,000 motorcycle licence holders in South Australia. People aged 45+ account for around 50% of registered motorcycles (25,000) and 41% of motorcycle rider serious casualties. Table 1 indicates that over the past 5 years, the number of registered motorcycles in South Australia has increased by approximately 10% from 2010 to 2014, whilst the number of motorcycle rider casualties has been relatively constant.

Table 1: Registered motorcycles and motorcycle rider casualties, SA, 2010 - 2014

Year	Motorcycles registered	Motorcycle rider fatalities	Motorcycle rider serious injuries	Motorcycle rider minor injuries
2010	47,000	16	146	388
2011	48,000	20	143	361
2012	49,000	13	113	339
2013	50,000	12	129	369
2014	51,000	11	127	417

Table 2: Motorcycle riders killed or injured aged 45 and over and the proportion of all motorcycle riders killed or injured, South Australia, 2010-2014

Year	Number and per cent of Motorcycle rider fatalities aged 45+	Number and per cent of Motorcycle rider serious injuries aged 45+	Number and per cent of Motorcycle rider minor injuries aged 45+
2010	10 (63%)	64 (44%)	127 (33%)
2011	4 (20%)	52 (36%)	110 (30%)
2012	7 (54%)	39 (35%)	99 (29%)
2013	5 (42%)	56 (43%)	134 (36%)
2014	4 (36%)	58 (46%)	154 (37%)
Total	**30 (42%)**	**269 (41%)**	**624 (33%)**

Table 2 indicates that for the 5 years (2010-2014) more than 40% of motorcycle riders killed or seriously injured were aged 45 years or older and 33% with a minor injury were aged 45 or over.

The average age of motorcycle licence holders in South Australia is 52 years whilst the average age of registered motorcycle owners is 49 years. With 70% of motorcycle licence holders (120,000) in the 45+ age bracket it is possible that the demand for returning rider training could increase in future if dormant riders decide to return to riding.

Returning/Returned riders

Returning (or returned riders) are people who rode in the past, and after an extended period of not riding, decide to take up riding again. This cohort may face increased crash risks as a result of not maintaining safe riding skills and if they are riding a more powerful or different style motorcycle than the one they used to ride in the past.

Research by the Monash University Accident Research Centre (MUARC, 2002) found that compared to other riders, returned riders:

- ride less frequently and less distance, and
- are less likely to use a motorcycle for commuting and general transport.

The 2002 MUARC "Motorcycling after 30" report also found that compared to continuing riders, returned riders are:

- more likely to nominate a car as their main means of transport
- less likely to have commuted in the past and more likely to have stopped commuting
- more likely to have started touring
- less likely to have ridden on a farm in the past
- less likely to have ridden for general transport in the past
- less likely to have owned motorcycles with engine capacity greater than 750 cc in the past.

MUARC research identified that returned riders as more commonly weekend, fair-weather, recreational riders who are more likely to ride in rural areas and for whom motorcycling is more of a discretionary activity than for people who ride as a primary form of transport. The 2002 MUARC report concluded that the promotion of refresher training courses for licence holders returning to riding may be of benefit to improve skills and remind potential riders that their skills may not be up to scratch.

Austroads project SS1708: *Development of a National Graduated Licensing Scheme for Motorcycle Riders*, also identified that returned riders have a higher risk of crashing and outlined a number of options to identify and improve road safety for 'returning riders'. Options included interventions directed toward specific age groups and their motivation for riding including targeted education and training for older and returning riders.

Research helped in the development of South Australia's Road Safety Action Plan 2013-2016 priority to encourage returning riders to undertake a motorcycle skills refresher training course.

Identifying returned riders

Data analysis was undertaken to identify:

1. How many casualty crashes potentially involve returning riders. This analysis was time consuming and involved checking individual licence and registration records, due to the time constraints the fatality number was used to estimate the number of serious and minor injuries potentially involving returning riders.
2. How many returned riders there are likely to be in South Australia.

Motorcyclist serious casualty crash data in the Traffic Accident Reporting System (TARS) for the period from 2007-2012 was analysed by DPTI Statisticians. For each motorcycle rider fatality, the rider licence number was checked on the Transport Regulation User Management Processing System (TRUMPS) vehicle registration and licensing database to determine if the rider was 45 years or over at the time of the crash. The riders were identified as a possible returning rider if they were aged 45 years or older, had held a motorcycle licence longer than 10 years and had a motorcycle registered to them for less than 6 months & did not have a motorcycle registered to them for period no less than 5 years prior to the one they were riding when they crashed.

The data analysis indicates that over the period from 2007 - 2012 nine motorcycle riders killed were potentially returning riders. Applying this analysis to the rider casualty data it is estimated that 13 motorcycle rider serious injuries and 28 minor injuries per year could also potentially be returning riders. It is possible that some of these casualty crashes may have been avoided if these riders had undertaken a riding skill refresher training course.

Rider Safe database records were also analysed to determine how many of motorcycle riders killed, who were identified as possible returned riders, had previously undertaken the rider safe training course. Only 25% of the people identified as possible returning riders had undertaken the rider safe training program.

To identify how many returned riders there were likely to be in South Australia at any one time, TRUMPS database was analysed to identify clients who:

1. have a current R or R-Date (restricted) class licence
2. are aged over 45 years
3. have held their motorcycle licence endorsement for 10+years
4. have currently a motorcycle registered to them for less than 6 months

5. did not have a motorcycle registered to them(as an individual or as part of a group) for period no less than 5 years prior to the motorcycle they have now.

A TRUMPS database query was conducted in December 2014 and this identified that there were 250 clients who met the returning rider criteria.

Training course development

The Rider Safe program in South Australia commenced in 1987 to ensure that novice motorcycle riders complete both the basic and advanced levels of the training course and have the skills required to be licensed to ride a motorcycle on public roads. Prior to 1987 there was no requirement to undertake any formal motorcycle rider training program as part of the licensing process, and as such, motorcycle licence holders born before 1971 (people aged 45+) may not have undertaken rider safe training.

It was decided that returning rider training would be conducted by Rider Safe because it was established in terms of existing purpose built off road training ranges, experienced expert instructors, booking program services, motorcycles and support facilities. Rider Safe is also well known and generally recognised as a comprehensive, research based rider education and training system.

In 2014, the Rider Safe training program curriculum was analysed to identify which skill areas should be covered by a returning rider training course. The underlying objective of the skills training course is to improve returned rider safety on the road. Rider Safe training facilities cater for groups of up to ten riders at a time and the decision was made that a half day training course would be developed for delivery at the Rider Safe training ranges throughout the State on a demand basis based on people booking into the course.

A draft returning rider course manual was developed by the Rider Safe Coordinator that covered a wide range of motorcycle handling skills such as braking, stopping quickly, turning and cornering, weaving, swerving, limited space manoeuvres, crossing over obstacles and gap selection. The returning rider training program would involve a series of class room briefing sessions and discussions followed by practical range riding skill practice sessions where participant's techniques could be checked and feedback provided. In late 2014 the Rider Safe training instructors ran internal pilot tests of the course to check content, materials and to ensure that flow and delivery could be achieved in a 3.5 hour time allocation.

Refinements to the course were made based on the pilot test experience and it was decided that a formal testing of the proposed course would be conducted early in 2015 involving experienced rider representatives from the Ulysses Motorcycle Club as well as a sample of returning riders. A news article about the training was posted on the DPTI intranet seeking dormant riders who were willing to volunteer to participate in the returning rider training course.

On 10 April 2015 the returning rider training course was further tested at the St Agnes training range in Adelaide with the group of volunteer motorcycle licence holders including several people who had not ridden a motorcycle for over ten years. Course participants were asked to provide comments in response to questions on a feedback form. Feedback from the course participants indicated unanimous support for the program and that the course content covered all the necessary skills to help a returning rider stay safe on the road. The feedback also enabled minor changes to be made to further develop and refine the course content ready for implementation.

Course participants who hadn’t ridden for many years noted how physically tiring motorcycle riding was due to the use muscles that were not used for car driving. The skills required for exercises such as weaving through cones, coming to a quick stop, obstacle swerving, and cornering manoeuvring, reminded motorcycle licence holders of the challenges involved in developing a safe riding technique.

The Motorcycle Reference Group, comprising key road safety stakeholders and motorcycle industry representatives were consulted and have been involved in the development of the returning rider training course. It was acknowledged that even though a returning rider’s experience is likely to vary greatly the training course should be aimed at the least experienced least confident riders although any holder of a South Australian motorcycle licence will be eligible to attend.

A September 2015 implementation date has been identified as the warmer weather following winter is traditionally a time when people choose to return to riding. The cost to undertake the training will be determined on user pays basis to cover the marginal cost associated with conducting returning rider training courses. The Ulysses Club has indicated that it will subsidise its member’s attendance at the course on a 50:50 cost sharing basis. At the time of writing this paper the subsidised fee that would be charged for participating in the returning rider training course was yet to be finalised.

Plans have been made to send letters from the Registrar of Motor Vehicles to licence holders identified as returned riders about motorcyclist road safety along with a brochure about the returning rider training course, including details about how to enrol in the returning rider course.

A public awareness / communications campaign is also planned to be undertaken to notify motorcycle licence holders about the training course and encouraging returning riders to undertake the training.

Conclusion

Implementing a returning rider training course and encouraging returning riders to undertake a motorcycle skills refresher training is one of several motorcycling road safety initiatives in South Australia's Road Safety Action Plan. Other motorcycling road safety priorities include:

- Investing in motorcycle safety infrastructure improvements and other possible enhancements,
- Developing 'sharing the road' education campaigns to raise drivers' awareness of safe behaviours in the presence of motorcyclists,
- Reducing the risk for motorcycle riders by enhancing the motorcycle licensing scheme and consider options to increase the uptake of motorcycles fitted with antilock braking system,
- Developing strategies to encourage the take up of motorcycles fitted with antilock braking systems and stability control systems, and
- Promoting the benefits of wearing protective motorcycle clothing.

The motorcycle skills refresher training course for returning riders will be evaluated to determine whether riders who undertake the refresher training are involved in fewer crashes than other returning riders. Motorcycle casualty crash data for riders aged 45+ will continue to be monitored and analysed to identify what other innovative motorcycling road safety education, training, engineering and enforcement initiatives can be implemented to reduce motorcyclist road trauma.

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Drivers' attitudes and knowledge regarding motorcycle lane filtering practices

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Abstract

Lane filtering occurs when a motorcyclist moves alongside stationary or slow-moving vehicles, with the motorcyclist sharing the lane or travelling between lanes. The practice is illegal in most Australian jurisdictions, but was recently legalised in New South Wales and Queensland. In February 2015, the Australian Capital Territory (ACT) commenced a two-year lane filtering trial. Prior to this, during December 2014 and January 2015, we surveyed 249 drivers (132 male, 117 female) aged 16-82 years (M = 41.4, SD = 14.5) regarding their attitudes towards and knowledge of lane filtering. Most drivers (61%) reported witnessing lane filtering at least once per week. Many drivers (28%) mistakenly believed lane filtering was already legal in the ACT, but 70% stated it should be illegal. Drivers were significantly more likely to agree lane filtering should be legal if they believed it was already legal (OR 4.67), rode a PTW themselves (OR 4.87), or were older (OR 1.03). Reasons for endorsing lane filtering varied, but included: easing traffic congestion; improving safety; personal freedom; and difficulty enforcing lane filtering prohibitions. Reasons for opposing lane filtering primarily related to safety concerns and drivers' difficulties in perceiving motorcycles (e.g., in blind spots). Our results provide insight into drivers' attitudes towards lane filtering, which can be used to raise public awareness about motorcycle safety and highlight key areas where empirical evidence is needed, since this is a topic that has historically received relatively little focus among researchers.

Introduction

Powered two-wheelers (PTWs) include motorcycles, mopeds and scooters, all of which differ from other motor vehicles in that they have the physical manoeuvrability to travel between circumscribed traffic lanes. Several different terms have been used to describe this behaviour, including lane filtering, lane splitting, and lane sharing (Sperley & Pietz, 2010), with some PTW riders colloquially referring to the practice as "white-lining" or "stripe-riding". Some road safety researchers and practitioners use these terms interchangeably, whereas others use distinct terms to differentiate whether riders are moving between lanes of stationary or moving traffic. Where this distinction is made, *lane filtering* refers to a rider passing between two lanes of traffic that is stopped or moving very slowly (e.g., slower than 30 km/h; ACT Government, 2014), whereas *lane splitting* refers to a rider passing between two lanes of moving traffic, and *lane sharing* is used as an umbrella term encompassing both filtering and splitting (Sperley & Pietz, 2010).

There are currently very few empirical studies regarding lane sharing (Aupetit, Espié, & Bouaziz, 2015; Mulvihill et al., 2013; Sperley & Pietz, 2010). Some research addresses lane sharing in a limited way, as part of broader investigations into motorcycle safety (e.g., Crundall, Bibby, Clarke, Ward, & Bartle, 2008). Existing research can be classified into three broad categories: crash investigations; self-report studies; and on-road studies.

Crash investigations

In-depth crash investigations have indicated that a small proportion of crashes involve a PTW rider who is lane filtering or splitting, with specific estimates ranging from 0.5% in the European Motorcycle Accident In-Depth Study (MAIDS; ACEM, 2009) to 5% in the United Kingdom (UK; Clarke, Ward, Bartle, & Truman, 2004), where the practice is legal.

In their crash analysis, Clarke et al. (2004) suggested that filtering motorcyclists violate drivers' expectations by appearing between lanes, where four-wheeled vehicles cannot travel, and as a consequence drivers may fail to look for or "look-but-fail-to-see" filtering motorcyclists. Consistent with this, on-road studies have suggested that drivers' schemata or mental models when exploring the road environment are focused on detecting other cars at the expense of motorcyclists and cyclists (Salmon, Lenné, Walker, Stanton, & Filtness, 2014; Salmon, Young, & Cornelissen, 2013). It is worth noting that "looked-but-failed-to-see" errors have been proposed as underlying a large proportion of *all* car-motorcycle collisions (ACEM, 2009), particularly right-of-way-violation collisions (Clarke, Ward, Bartle, & Truman, 2007; Hancock, Oron-Gilad, & Thom, 2005) and these errors and inadequate expectations are by no means limited to the context of lane filtering.

Self-report studies

Self-report studies include interviews, focus groups and surveys that are designed to elicit individuals' attitudes and perceptions regarding lane filtering, as well as riders' engagement in the practice. Most self-report research has focused on PTW riders, revealing that riders commonly undertake lane filtering and believe it is relatively low risk (Blackman & Haworth, 2010), helps maintain traffic flow (Huth, Füssl, & Risser, 2014), increases trip efficiency and has the potential to improve rider safety (Regan, Lintern, Hutchinson, & Turetschek, 2009, 2015). However, respondents also note that car drivers sometimes act inappropriately around PTWs because they do not understand or anticipate the full range of manoeuvres that a PTW may undertake, including lane filtering (Huth et al., 2014).

Although filtering is widespread, riders report adjusting their behaviours based on traffic conditions (Regan et al., 2009) and social influences (Tunnicliff, Watson, White, Lewis, & Wishart, 2011). For instance, one participant in a Queensland-based focus group study reported that he would not lane split in front of his son (Tunnicliff et al., 2011), suggesting that some riders perceive lane sharing has a negative or dangerous image. In the same study, a rider training instructor noted that lane filtering is safe, but they do not tell new riders that because they are less adept at filtering than more experienced riders (Tunnicliff et al., 2011).

There is minimal research examining car drivers' perceptions of lane filtering. In the UK, where filtering is legal, Crundall et al. (2008) found that most drivers correctly identified that motorcycle riders were permitted to filter through stationary or slow-moving traffic. When asked to rate their agreement with the statement "*When in slow moving traffic I am often surprised by motorcyclists filtering through the traffic*" on a 7-point scale, average ratings for both males and females were close to the midpoint (Crundall et al., 2008). These findings suggests that UK drivers have reasonable awareness of lane filtering; however, different results may be obtained in jurisdictions where filtering remains illegal.

On-road studies

On-road studies using motorcycles are relatively new. These include both instrumented vehicle studies where riders are monitored while completing a prescribed route, and naturalistic studies where participants' daily travel is recorded via cameras and data loggers. In recent years, two published on-road studies have explicitly focused on lane filtering (Aupetit et al., 2015; Mulvihill et al., 2013).

In an instrumented vehicle study of 25 motorcyclists in Melbourne, Australia, Mulvihill et al. (2013) found that riders engaged in lane filtering on 27% of occasions where it was physically possible. Filtering on approach to intersections was associated with diminished situation awareness, as measured by concurrent verbal protocols provided during the ride. Motorcyclists who filtered through the traffic queue focused more on their own actions and less on perceiving the broader road environment (Mulvihill et al., 2013). A limitation of this study was that participants completed a single 15 km test route, in which they were exposed to a small number of intersections and therefore had few opportunities to engage in lane filtering.

Aupetit et al. (2015) conducted a longer-term naturalistic study, in which 11 motorcyclists from Paris, France, rode an instrumented motorcycle for a month. Lane sharing is illegal but is tolerated and widely practiced in Paris. During the study participants spent approximately 72% of their time riding between lanes (Aupetit et al., 2015). The authors did not differentiate between filtering and splitting, but their results indicate that participants engaged in both, since they explicitly referred to travelling at speeds in excess of 30 km/h. Follow-up interviews with the riders indicated that lane filtering and splitting are cognitively demanding tasks, requiring riders to accurately perceive and interpret the behaviour of other road users in order to safely negotiate traffic and know when lane sharing would be unsafe or might impair other road users' ability to detect the PTW (Aupetit et al., 2015).

Legality of lane sharing

Whereas lane splitting at high speeds is typically illegal, the legality of lane filtering through stationary or very slow traffic varies between jurisdictions. Filtering is legal in several European countries, but is illegal throughout most of the USA. Even in jurisdictions where it remains illegal lane filtering appears to be relatively common, with riders arguing that it should be legal because it would improve both safety and traffic congestion (e.g., Blackman & Haworth, 2010; Huth et al., 2014; Regan et al., 2009). Some researchers have also recommended that governments consider legalising lane filtering, given that prohibitions are difficult to enforce and legalising filtering has the potential to confer safety benefits. For instance, Aupetit et al. (2015) noted that lane splitting demands skills that motorcyclists do not learn in formal training, and therefore riders must acquire these skills through trial and error during daily riding. If it were legalised, filtering skills could be taught during training, which could potentially improve safety and reduce crash risk (Aupetit et al., 2015). Legalising lane filtering would also mean that driver training could be adapted to include recognition and awareness of filtering PTWs.

The state of New South Wales was the first Australian jurisdiction to legalise lane filtering, in July 2014, followed by Queensland in February 2015. The legalisation of lane filtering in NSW followed a two-month trial of lane filtering within Sydney central business district from 1 March 2013 to 30 April 2013. Trial outcomes were evaluated with respect to safety, traffic congestion, and the behaviour and attitudes of road users (Centre for Road Safety, 2014). Evaluation of the trial found no measurable impact on congestion; this was likely due to the fact that filtering motorcycles comprised only 1% of traffic (motorcycles overall constitute approximately 4% of Sydney traffic, but observational data indicated only 20-30% of motorcycles engaged in filtering during the trial period). There were no motorcycle crashes and only one near-miss recorded during the trial period, which was interpreted as indicating that lane filtering is not associated with safety disbenefits for PTW riders (Centre for Road Safety, 2014); however, this finding should be interpreted with caution given that it was a relatively short trial in part of one city. In summary, it appears that there was no change in either traffic congestion or motorcycle crash rates during the short-term trial of lane filtering in central Sydney. Observational data suggested that filtering has the potential to increase PTW-pedestrian collisions and for this reason the NSW Centre for Road Safety (2014) recommended that 30 km/h was the optimal maximum speed that should be permitted for filtering, in order to minimise the likelihood of a fatal pedestrian/motorcycle collision.

ACT lane filtering trial

In June 2014 the Australian Capital Territory (ACT) Standing Committee on Planning, Environment and Territory and Municipal Services tabled a report on their Inquiry into Vulnerable Road Users (Standing Committee on Planning, Environment and Territory and Municipal Services, 2014). The parameters of this inquiry were to examine best practice approaches to protecting vulnerable road users, including PTW riders, and to make recommendations for improving the safety of vulnerable road users. The report contained 28 recommendations, including a recommendation that the ACT conduct its own trial of lane filtering (Standing Committee on Planning, Environment and Territory and Municipal Services, 2014).

In response to this recommendation, the ACT government initiated a two-year trial of lane filtering, which commenced on 1 February 2015. Legalising lane filtering within the ACT would maintain consistency with NSW, which is valuable since the ACT is completely enclaved within NSW and many ACT residents drive regularly in NSW. Noting that the NSW trial was of relatively short duration, and therefore did not yield conclusive evidence regarding any potential benefits or disbenefits of lane filtering, the ACT government sought to conduct a longer trial in order to undertake more comprehensive evaluation of the safety consequences of lane filtering.

Since traffic densities are considerably lower in the ACT compared to Sydney, the trial is expected to have negligible impact on congestion. Formal evaluation of the trial will therefore focus on safety outcomes, examining changes in the rate of same direction, lane change and side-swipe collisions involving PTWs (which are proposed as proxy measures of filtering crashes, since lane filtering and lane splitting are not coded in crash records; ACT Government, 2014). A major motivation for legalising filtering is the potential to reduce collisions in which other road users rear-end or side-swipe PTW riders, and to increase drivers' awareness of PTWs more generally (Standing Committee on Planning, Environment and Territory and Municipal Services, 2014). However, it is worth noting that these hypothesised benefits are merely conjecture, since no previous research has systematically investigated whether lane filtering impacts motorcyclists' safety.

The aim of the current study was to explore drivers' knowledge of and attitudes towards lane filtering. As noted above, there is limited research investigating drivers' attitudes towards lane filtering, despite the fact that drivers have an integral part to play. If drivers do not endorse lane filtering, then they may behave in a hostile, aggressive, or otherwise unaccommodating manner towards riders who attempt to filter through traffic queues (e.g., positioning their vehicle so that there is insufficient room for motorcyclists to pass between lanes). The current analysis presents data on drivers' general attitudes to lane filtering, particularly focusing on their opinions regarding whether it should be legalised and why. The sample included Canberra region residents and visitors to Canberra. Data was collected before the commencement of widespread media campaigns intended to raise drivers' awareness of lane filtering specifically and motorcycle safety more generally.

Method

Participants

Overall 250 participants completed the survey, but data from one participant was excluded because they did not possess a driver's licence. The remaining 249 drivers (132 male, 117 female) were aged 16-82 years (M = 41.4, SD = 14.9). All provided informed consent and participated voluntarily. Ethical aspects of the research were approved by the ANU Human Research Ethics Committee.

Most participants (63%) ordinarily resided in ACT or NSW, with the remainder residing in Victoria (12%), Queensland (9%), South Australia (6%), other Australian states/territories (3%), New Zealand (3%), or other overseas countries (4%). Among the 155 participants residing in ACT and NSW, 73 lived in the Canberra region (ACT and nearby NSW including Queanbeyan, Sutton, Jerrabomberra) and 82 lived in Sydney or other regional areas of NSW.

Materials

The survey contained three sections: demographic information; transportation use; and lane filtering. In the *demographic information* section, participants reported their age, sex and location of residence. In the *transportation use* section, participants reported the type of driver's licence held, jurisdiction in which they obtained their licence, their preferred transportation mode, and whether they or anyone close to them rode a PTW.

In the *lane filtering* section, participants were asked whether they had heard of lane filtering (noting that the practice was also referred to as lane splitting, white-lining or stripe-riding). If they had heard any of these terms, they were prompted to provide a definition of what the practice entailed. For participants who had not heard of lane filtering, a researcher provided a verbal definition. Participants were then asked to report how frequently they witness motorcyclists engaging in lane filtering and whether filtering was legal at that time in the ACT. Finally, participants were asked to indicate whether they believed that lane filtering should be legal or illegal, and to explain their position.

Procedure

Participants were recruited to complete a short road safety study conducted on-site at Questacon, the National Science and Technology Centre, which is a public museum located in Canberra, ACT. The study was conducted over a one-month period between 16 December 2014 and 13 January 2015. This time period was chosen because it was shortly before the commencement of the ACT lane filtering trial, which began on 1 February 2015, and preceded television and radio broadcast campaigns publicising the trial, which began on 23 January 2015.

The study comprised two computer-based tasks: an experiment examining attention and hazard perception in road scenes, followed by the survey. The current paper reports only the survey results. The survey was programmed using Qualtrics Online Survey Software. Participants completed the survey on computer with a researcher present to assist and clarify any questions if necessary. On average, the survey took 8-10 minutes to complete.

Results

Transportation use

Nearly all respondents (91%) held a full driver's licence, with relatively few being on a provisional licence (5%) or learner's permit (4%). The average duration of licensure was 26 years (SD = 14.1; range 1-65) for fully licensed drivers and 1.9 years (SD = 1.1; range 1-4) for provisional drivers.

The majority of participants (86%) reported their preferred transport mode was driving a car. Riding a bicycle and public transport were each nominated by 5% of participants, with 3% nominating riding a motorcycle as their preferred transport mode and only 1% nominating travelling on foot. Nearly four-fifths indicated that they used their preferred transport mode 5-7 times per week (78%), with 14% travelling 2-4 days per week and 6% using their preferred transport mode less than once a week.

Most participants (90%) did not ride any form of PTW. Motorcycles were the most common PTW used, with 9% of respondents reporting that they ride a motorcycle. One participant reporting riding a moped, and none reporting using a motorised scooter. Although very few participants reported riding a PTW themselves, 32% had a first-degree relative, partner or close friend who rides a PTW.

Lane filtering

Approximately two-thirds of the sample reported that they had not previously heard of any of the terms used to describe lane filtering (66%) and were unable to define what it entailed (67%).

Most respondents who provided a definition of lane filtering conveyed an accurate understanding of the practice. The amount of detail provided in their descriptions varied, but responses were coded as correct if they made reference to motorcyclists passing slower-moving cars and/or moving between lanes. A small proportion of respondents (4%) provided an incorrect definition, with most incorrect definitions focusing on situations in which two lanes of traffic merged. Two participants provided responses that indicated they possibly understood the concept of lane filtering, since they indicated that it involved undesirable or potentially dangerous behaviour by motorcyclists (and later affirmed it should be illegal), but did not describe it properly.

Over half the sample reported that they witnessed motorcyclists engaging in lane filtering on average at least once per week. This was fairly evenly divided between participants who reported seeing lane filtering 5-7 days per week (20%), 2-4 days per week (23%) and once per week (17%). A further 12% reported seeing filtering motorcyclists 2-3 times per month, 8% see filtering on average once per month, 9% see it less than once a month, 4% almost never see lane filtering and 5% had never seen it at all. For the purposes of subsequent analyses, frequency of witnessing lane filtering was dichotomised as “at least weekly” (61%) and “less than weekly” (39%).

When asked whether lane filtering was currently legal in the ACT, overall 28% of respondents erroneously indicated that it was legal. Chi-square tests indicated that beliefs about the legality of lane filtering did not differ depending on where the respondent usually lived, $\chi^2(8) = 5.50$, $p = .726$, Cramer’s $V = .15$. Specifically, 26% of ACT residents, 31% of NSW residents and 23% of Queenslanders and Victorians believed lane filtering was already legal in the ACT. This finding suggests that respondents were not biased by the laws in their own state of residence.

Finally, when asked to indicate whether they thought lane filtering should be legal, only 30% agreed. Again, chi-square tests indicated that opinions did not differ depending on where the respondents normally lived, $\chi^2(8) = 3.32$, $p = .923$, Cramer’s $V = .12$. The proportion indicating that lane filtering should be legal ranged from 23% in Victoria to 34% in NSW. (The Northern Territory was an outlier, in that no respondents indicated that lane filtering should be legal, but this sample consisted of only three individuals so no conclusions can be drawn from this data.)

Among respondents who believed that lane filtering should remain illegal, the predominant reason for this opinion was safety. Respondents expressed concern that it would be difficult for drivers to perceive motorcyclists (and cyclists) who engaged in lane filtering, which could lead to drivers hitting riders if they opened their car door or changed lanes suddenly. Several respondents noted that motorcyclists are hard to see, and that filtering motorcyclists would violate drivers’ expectations and catch them off guard. A small proportion indicated filtering should be illegal because all motorists should be bound by the same rules.

Some respondents who suggested that filtering should not be legal noted that there may be some circumstances in which it could be permissible, specifically if the cars were completely stationary, traffic lights were red and there was sufficient room between lanes. However, one respondent expressed concern that it would be too complex for the road rules to fully capture the conditions in which it would versus would not be safe to filter and thus concluded that it should be prohibited.

Whereas respondents opposed to lane filtering focused predominantly on safety, those in favour of legalising lane filtering offered up a more diverse set of responses. Respondents suggested that filtering could ease traffic congestion and improve safety, by allowing motorcyclists to effectively separate themselves from other vehicles at intersections (i.e., moving to the front of the queue and then crossing quickly when the lights turn green). Others argued that riders filter regardless of the laws, so it might as well be legal. Another theme that emerged was personal freedom: that is, even if lane filtering poses a slight risk, individuals should be entitled to take some risks on the road. Finally, some respondents believed that legalising lane filtering would raise drivers' awareness of PTWs on the road, and noted that (to their knowledge) there are no obvious safety concerns in jurisdictions where the practice is legal and/or widespread.

Many respondents in favour of lane filtering qualified this by saying that lane filtering should only be done under specific circumstances, but in general they considered it was a safe practice. One respondent suggested that it should be permitted for experienced riders, but not learners.

Predictors of attitudes towards lane filtering

To explore factors that were associated with attitudes towards lane filtering, we ran a logistic regression. The dependent variable was opinions regarding whether lane filtering should be legal, a binary variable. Six variables were selected as possible predictors: age in years; sex (female vs. male); riding a PTW (no vs. yes); having a close relative or friend who rides a PTW (no vs. yes); frequency of witnessing lane filtering (less than once a week vs. at least weekly); and belief that lane filtering is already legal in the ACT (currently illegal vs. currently legal). Age was entered as a continuous variable; all other variables were entered as categorical with the first listed category used as the reference group. The full model with all predictors was significantly different to the constant-only model, $\chi^2(6, N = 249) = 47.02$, $p < .0005$, Nagelkerke $R^2 = .26$.

As shown in Table 1, three variables significantly predicted opinions regarding whether lane filtering should be legal, when including the full sample. Specifically, respondents were more likely to agree that lane filtering should be legal if they were older, rode a PTW themselves, and believed that lane filtering was already legal in the ACT. Frequency of exposure to motorcyclists engaging in lane filtering and having a relative or close friend who rides a PTW did not predict opinions regarding whether lane filtering should be legal.

There was a trend where males were more likely to endorse legalising lane filtering than females, but sex was not a significant predictor when PTW-riding status was entered in the model because males were significantly more likely than females to be PTW riders (14% vs. 4%), $\chi^2(1) = 6.49$, $p = .015$, Cramer's $V = .16$.

Table 1. Results of binary logistic regression predicting opinions regarding whether lane filtering should be legal

Variable	B	SE	Wald χ^2	Odds Ratio	95% CI OR
Age	0.03	0.01	7.82^{**}	1.03	[1.01, 1.05]
Sex	0.51	0.34	2.24	1.66	[0.86, 3.22]
Ride a PTW	1.58	0.55	8.40^{**}	4.87	[1.67, 14.22]
Friend/relative rides a PTW	0.45	0.36	1.58	1.56	[0.78, 3.14]
See lane filtering frequently	-0.14	0.33	0.18	0.87	[0.45, 1.67]
Believe filtering is already legal	1.54	0.34	20.06^{***}	4.67	[2.38, 9.18]

** $p < .01$, *** $p < .001$

A second logistic regression was run including only participants who resided in the Canberra region. Since this sample was smaller ($n = 73$), predictor variables were only included if they showed statistically significant relationships in the original analysis. (Note that all variables demonstrated the same trends in both the Canberra region subsample and the full sample.)

The Canberra-specific model with three predictors (age, ride a PTW, believe filtering is already legal) was significantly different to the constant-only model, $\chi^2(3, N = 73) = 8.90$, $p = .031$, Nagelkerke $R^2 = .16$. Age remained a significant predictor of attitudes towards lane filtering, OR 1.03, 95% CI OR [1.001, 1.07], as did belief that lane filtering was already legal, OR 3.36, 95% CI OR [1.06, 10.69]. However, riding a PTW was not a significant predictor in the Canberra subsample: OR 2.42, 95% CI OR [0.34, 17.07]. This was due to small sample size, since only five Canberra-based respondents rode PTWs.

Discussion

The current study indicates that over two-thirds of drivers do not support legalising lane filtering. Three factors were significantly associated with opinions of lane filtering: age of the individual surveyed, whether they rode a PTW themselves, and whether they believed lane filtering was already legal in the ACT. The fact that dual driver-riders were more likely to support lane filtering is consistent with previous research, which has reliably found that PTW riders believe that lane filtering is safe and should be legalised (e.g., Blackman & Haworth, 2010; Huth et al., 2014; Regan et al., 2009, 2015). The fact that age predicted attitudes was also consistent with UK research surveying drivers' attitudes towards motorcyclists, which found that more experienced drivers held more positive and sympathetic attitudes towards riders (Crundall et al., 2008).

Overall it appears that attitudes towards lane filtering and especially opinions regarding its safety are divergent between PTW riders and non-riders. Whereas surveys of riders consistently reveal a belief that filtering should be legalised to improve safety, our results indicate that drivers believe that lane filtering is unsafe and should remain illegal. At present, these opposing views cannot be reconciled since there is insufficient evidence regarding the safety of lane filtering. Although there are no demonstrated safety disbenefits of lane filtering, there is also no evidence to conclude that it improves safety (Regan et al., 2015). If lane filtering does indeed impact motorcyclist safety, then crash analyses from the current ACT lane filtering trial may provide useful evidence, but given the relatively small population of the ACT, even two years' worth of data may provide insufficient numbers to demonstrate a meaningful effect.

This highlights a challenge for road safety policy in Australia, especially given that lane filtering has recently been legalised in two jurisdictions. If lane filtering proves to be safe and is therefore legalised in the ACT and other Australian jurisdictions, then conclusive evidence will need to be presented to drivers to persuade them that lane filtering is safe (given that drivers' most common objection *against* lane filtering was that they perceive it to be unsafe) and that they should behave respectfully towards PTW riders who engage in legal filtering.

Alternatively, if the current ACT trial (or other evidence not yet available) demonstrates that lane filtering has safety disbenefits, then the challenge is to communicate this finding to PTW riders in a way that is sufficiently compelling to dissuade them from undertaking filtering. Although there is limited evidence regarding the safety of lane filtering, on-road studies have suggested it has the potential to negatively impact safety since it is cognitively demanding and reduces riders' situation awareness (Aupetit et al., 2015; Mulvihill et al., 2013).

A further potential challenge, if lane filtering remains illegal in some jurisdictions, lies in addressing the inconsistency in road laws. In particular, our results suggest that road users who endorse lane filtering perceive its legality in other jurisdictions as evidence that it is safe, despite the fact that there is no conclusive evidence to support either view. Thus the fact that filtering is already legal in NSW and Queensland may create resistance if, at the conclusion of the current ACT trial, legislators ultimately decide that lane filtering should not be permanently legalised. If this occurs, then compelling evidence would need to be presented to those road users who supported the legalisation of lane filtering, particularly PTW riders.

The common concern expressed by drivers that they may fail to detect motorcyclists is consistent with empirical research indicating that drivers do indeed possess inadequate schemata for detecting motorcyclists (e.g., Clarke et al., 2004; Salmon et al., 2013, 2014). This is challenging to remedy, since schemata are formed and reformed through years of experience. However, it is encouraging that drivers are aware of their perceptual limitations when searching for motorcyclists. This highlights another area where greater education and awareness could be beneficial, by making PTW riders more "cognitively salient" to drivers and ultimately reducing the likelihood that drivers will "look-at-but-fail-to-see" motorcyclists. Road users who support lane filtering have suggested that legalising the practice could be one way to make drivers more aware of motorcyclists. Thus one avenue for future research could include examining whether changes in the legality and/or prevalence of lane filtering have any impact on drivers' perceptual abilities to detect PTWs on the road.

A minority of drivers appear to oppose lane filtering on ideological grounds. Specifically, a number of drivers believed that laws should be consistent between different classes of road users to maintain consistency and fairness. This includes the idea that PTW riders should just be patient and wait their turn. Although this appears to be a minority opinion, in jurisdictions where lane filtering is (or may become) legal, it would be worthwhile attempting to identify ways in which lane filtering could benefit drivers in order to minimise the potential for aggressive and hostile interactions between road users. Given that the effects of lane filtering on traffic congestion are negligible, more research would be required in order to identify evidence-based benefits.

Whereas safety was a reason for most drivers opposing lane filtering, it was also provided by many as a reason for supporting the legalisation of lane filtering. This paradox is interesting, in that it highlights that drivers may have divergent opinions about the risks and benefits of a given traffic manoeuvre or practice based on their unique accumulated experience. Again, this highlights the need for ongoing communication with the public regarding safe vs. unsafe road use, based on reliable empirical evidence, in order to minimise situations in which road users hold conflicting opinions about the safety consequences of engaging in a particular behaviour.

Overall, the current study adds to the existing motorcycle safety literature by providing insight into how drivers view lane filtering. In a context where lane filtering was illegal at the time, a substantial minority of drivers believed that it was legal, indicating confusion in the community over its status. However, more importantly, most drivers believed it should not be legalised, despite the fact that many of the drivers reside in jurisdictions where filtering is already legal (i.e., NSW, Queensland). This highlights that widespread public opinion does not necessarily support the recent move to legalise lane filtering in several Australian jurisdictions. Given that the predominant reason for opposing lane filtering was rider safety, there is considerable scope for changing drivers' attitudes through awareness campaigns highlighting that lane filtering is not dangerous, and can potentially improve rider safety in some situations.

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Greater understanding of rear-end crashes in a Safe System

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Abstract

Rear-end crashes contribute a significant proportion of the total fatal and serious injury (FSI) crashes occurring on Australian roads. Despite accounting for less than 2% of fatal crashes on Australian and New Zealand roads, this crash type accounts for an estimated 16% of serious injury crashes on urban roads and approximately 8% on rural roads. As such, road safety professionals seeking to drive down FSI crashes need to consider methods of addressing this crash type.

As rear-end crashes are generally less severe than other crash types, it may be tempting to assume that these crashes do not warrant attention when addressing crashes resulting in fatal or serious injuries. Further, since it is not possible to physically separate or shield the striking vehicle from the struck vehicle, developing options to treat the rear-end crash problem may be considered to consume too many resources for too little benefit.

This extended abstract describes the findings of an Austroads' study to identify factors contributing to the incidence and severity of rear-end crashes and treatments to reduce their occurrence or mitigate their severity. The study involved a literature review, detailed analysis of 5 years of crash data from Australia and New Zealand, and a comparison of common factors at crash sites in several states. The extended abstract discusses options within the four Safe System pillars for addressing rear-end crashes in order to answer the question: Is it worthwhile investing our resources in treating this crash type?

Background

Rear-end crashes feature significantly in jurisdictions' road crash statistics, accounting for about 40% of CTP insurance claims. Whilst most rear-end crashes are not fatal, a large proportion result in serious injuries, with about one-quarter being classed as fatal or serious injury crashes, warranting attention under the Safe System approach. As a result, almost 50 FSI rear-end crashes occur on average on Australian and New Zealand Roads each week.

Austroads commissioned a research project (Austroads 2015) exploring the contributory factors for rear-end crashes, especially those leading to fatal and serious injuries, in urban and rural locations. The project sought to identify appropriate solutions, with a particular focus on engineering treatments – both currently used and new potential treatments.

This extended abstract summarised key findings from this project. Further information may be found in the published report (Austroads 2015).

Method

To meet the research goals, a review of national and international literature was undertaken. The review identified previous investigations into factors associated with rear-end crashes in urban and rural environments, measures that may be used to prevent such crashes, and the effectiveness of these measures. Crash data over a five year study period (2006–10) was analysed, with a series of site investigations also conducted at 'high' crash sites in New South Wales, Victoria and Queensland. The purpose of these site investigations was to identify factors that may have contributed to the occurrence or severity of rear-end crashes.

Throughout the project, road environment, vehicle and driver characteristics were considered as potential crash contributory factors.

Findings

Crash contributory factors

Analysis of the crash data, together with the site investigations and literature review found the following environmental factors related to the rear-end crashes

- Crash rate is higher at intersections than midblock locations, due to a greater presence of slow-moving or stationary traffic.

- The crash rate is further elevated at signalised intersections compared to other intersections. Rear-end crashes at signalised intersections were greatly affected by driver decisions during the yellow phase. Drivers of lead vehicles may decide to stop, whilst the driver of the trailing vehicle may have intended to pass through. This issue is exacerbated when red light cameras are present, which may lead to drivers of lead vehicles braking more harshly during the yellow phase to avoid the risk of running a red light.

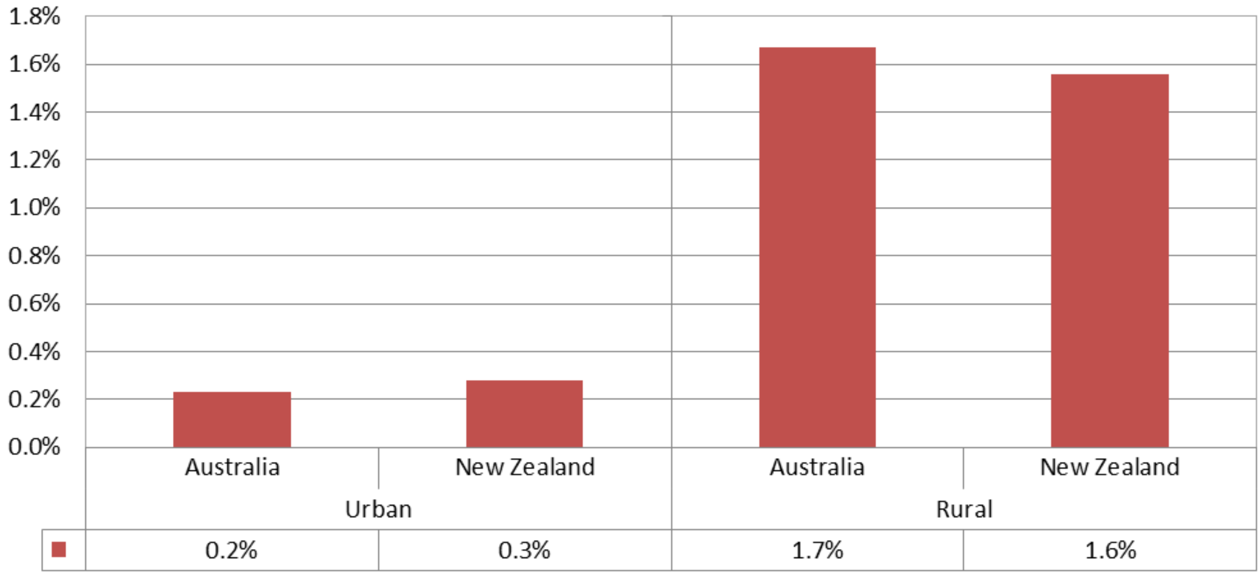
- Crash rate increases with increasing traffic density. As such, rear-end crashes tend to be related to times of peak hour traffic and on arterial roads, conditions where higher traffic volumes are expected.

- Rear-end crashes are more common in road work zones. This may be due to a higher traffic density, changes in traffic flow, and a higher incidence of heavy vehicles.

- Rear-end crashes are generally an urban crash type, with a 4.6 times as many FSI rear-end crashes occurring on urban roads than rural. The higher rate in urban environments can be understood when considering that most of the above environmental factors associated with rear-end crashes are more common in urban conditions.

  However, rear-end crashes in rural environments are generally more severe (Figure 1), most likely due to higher travel speeds resulting in a greater likelihood of higher impact speeds.

Figure 1. Proportion of rear-end casualty crashes (2006-10) resulting in a fatality by road environment



Driver-related factors for rear-end crashes include:

- Drivers that maintain a poor headway time gap with the vehicle ahead are at greater risk of rear-end crashes. There is no clear consensus of what is considered a safe headway amongst road agencies, so confusion amongst drivers is understandable. Drivers may also struggle to maintain a safe headway when traffic volumes are high as other vehicles may move into the space.

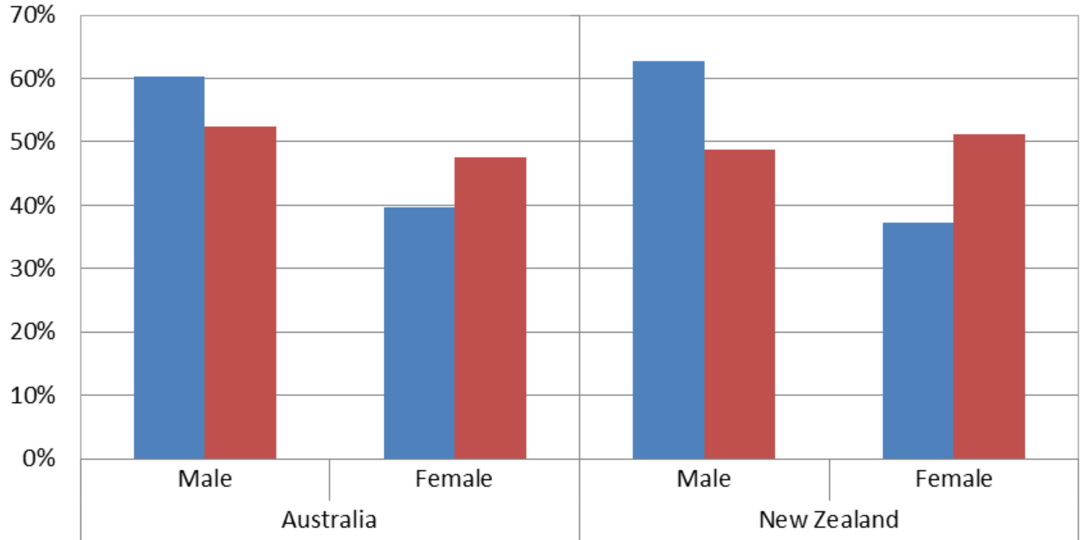
- Driver distraction and inattention is a common factor in rear-end crashes. This is most commonly due to an in-vehicle distraction, such as mobile phones, other passengers or radio. Another common type of driver distraction associated with this crash type is cognitive inattention, described as a driver having ‘looked but failed to see’.

  As driver distraction extends driver response times, and shorter headways require shorter response times, distracted drivers maintaining shorter headways would exacerbate both issues.

- Younger and older drivers are both more likely to be operating the striking vehicle in a rear-end crash. Younger driver risk is believed to be higher due to more risk-taking behaviour and poorer spatial awareness, resulting in poor maintenance of headway. Older drivers are believed to be at greater risk due to physical and cognitive impairments that delay their responses.

- Males are more likely to be operating the striking vehicle (Figure 2).

Figure 2. Proportion of urban rear-end casualty crashes (2006-10) in Australia and New Zealand by striking and struck driver gender

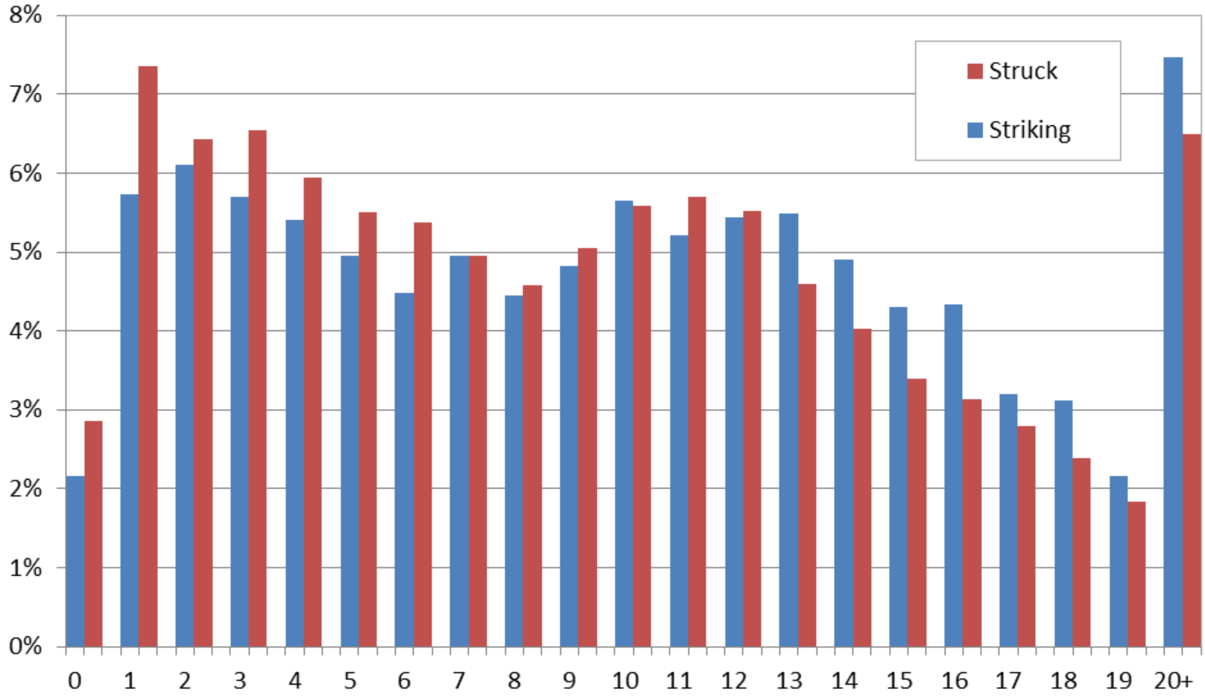


	Australia Male	Australia Female	New Zealand Male	New Zealand Female
Striking	60.3%	39.7%	62.7%	37.3%
Struck	52.4%	47.6%	48.8%	51.2%

Vehicle-related factors for rear-end crashes include:

- Larger vehicles, such as 4WDs and light trucks, restrict the sight distance of drivers following, reducing their ability to anticipate changes in traffic ahead. As such, these vehicles are at greater risk of being struck.
- Heavy vehicles are not able to decelerate as rapidly as smaller vehicles. As such, heavy vehicles are less likely to be struck, but more likely to strike a vehicle in a rear-end crash.
- Striking vehicles are more likely to be older than the struck vehicle in a rear-end crash, likely reflecting recent improvements in vehicle technology (Figure 3).

Figure 3. Proportion of rural rear-end casualty crashes (2006-10) in Australia and New Zealand by striking and struck vehicle age



Factors affecting injury outcomes in a rear-end crash include:

- Occupants in struck vehicles are more likely to sustain injuries than those in the striking vehicle.
- Older vehicles generally allow for a greater separation between an occupant's head and the head restraint. As the occupant's head has a greater range of motion the risk of whiplash injury increases.
- Females are more susceptible to injuries in rear-end crashes than males.

Potential countermeasures

Safety measures that could be effective were identified as either short-term measures that could be undertaken as part of a road maintenance program, or more substantial improvements to be undertaken as part of a capital works or road safety program.

Short term measures to treat rear-end crash sites include:

- Raise awareness of intersections, such as through improved or supplementary signage and delineation.
- Banning of turn movements through signage.
- Speed management, for example through lower speed limits and enforcement. This measure is particularly effective to improve vehicle headways in work zones.

More substantial treatment options include:

- Treatments to alert drivers of intersections, including rumble strips on approach and improvements to visibility of traffic signals and intersection lighting.
- Installation of exclusive turn lanes or median turn lanes to separate slow-moving or queued vehicles preparing for a turn from the general traffic flow. Turn lanes at capacity may need to be extended or a supplementary lane added.
- Co-ordination of traffic signals to encourage platooning of vehicles and reduce speed differentials along the route.
- Signalisation of turn movements to remove conflict between turning and through traffic.
- Replacement of red-light cameras with red-light speed cameras. These cameras counteract the rear-end crash increase associated with red-light cameras by encouraging more controlled speeds at the intersection.
- Installation of congestion advisory signs. These signs may be activated when traffic queuing is significant to alert approaching drivers to anticipate the need to decelerate.
- Tailgating measures, such as:
    - Vehicle-activated signs when a low headway time is detected.
    - Headway distance marking with accompanying signposting to inform drivers of the appropriate distance to maintain.
    - Hand-held headway enforcement cameras that may be used to detect and fine drivers maintaining a low headway. This system will be difficult to implement without headway times being mandated in state road rules.
- Variable speed signs to reduce congestion.

As well as road-engineering based countermeasures, there are a number of in-vehicle technologies being developed that could help reduce the rate of rear-end crashes. Forward collision avoidance technologies and brake assist will help a driver bring a vehicle to a halt before colliding with a vehicle ahead. Headway monitoring devices will warn drivers if they are maintaining too small a headway.

Future research

The study identified a number of opportunities for future research. These include studying the rear-end crash risk associated with disruptions to traffic flow (such as caused by bus stops and driveways), and with short yellow phase times at traffic signals. Also, it is recommended that measures aimed at reducing tailgating be investigated.

Conclusion

This research project highlighted the high number of injury crashes resulting from rear-end crashes. Whilst these crashes are generally less severe, the sheer number of rear-end crashes results in a large number of road users sustaining serious injuries, justifying the need to consider options to reduce the incidence and severity of this crash type.

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Safe System Auditing – principles to practice

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Abstract

The Safe System is a road safety philosophy that requires the road system to be designed and managed so that death and serious injury are avoidable. It consists of four core interrelated components: safer roads, safer speeds, safer vehicles, and safer people. It is a well-known principle that has been philosophically adopted by road authorities such as VicRoads. Converting the principle into action has been slower – because the natural tendency when undertaking infrastructure projects is to adopt normal practice and follow existing guidelines. Safe System Auditing is one tool being used by VicRoads to convert Safe System principles into practice.
Safe System Auditing is the formal safety examination of a road related program, project or initiative. such as:
• an existing road, intersection or length,
• a road investment project, whether at feasibility, design or pre-opening stage,
• a community road safety program or funding application,
• a road transport policy or strategy.

Safe System Audits distinctly 'raise the bar' beyond the work of a Road Safety Audit (RSA). A RSA qualitatively estimates and reports on potential road safety issues against current standards and guidelines but only identifies opportunities for improvements in safety in this 'limited' perspective, however a SSA measures compliance with Safe System principles which can, and does, push outcomes to a higher level - while at the same time considering realistic constraints.

VicRoads has engaged Safe System Solutions Pty Ltd to undertake a number of Safe System Audits of infrastructure projects the results of which will be described in this paper.

Definitions

Primary Treatment: Road planning, design and management consideration that virtually eliminates the potential of fatal or serious injuries occurring in association with the foreseeable crash types.

Step Towards: Road planning, design and management considerations that improve the overall level of safety associated with foreseeable crash types, but not expected to virtually eliminate the potential of fatal or serious injuries occurring. Also, when applied to an existing road environment, they improve the ability for a Primary Treatment to be implemented in the future.

Supporting Treatments: Road planning, design and management considerations that improve the overall level of safety associated with foreseeable crash types, but not expected to virtually eliminate the potential of fatal or serious injuries occurring. Also, when applied to an existing road environment, they do not change the ability for a primary treatment to be installed in the future.

Non-Safe System Treatment: Road planning, design and management considerations that are not expected to achieve an overall improvement in the level of safety associated with foreseeable crash types occurring, or when applied to an existing road environment, they reduce the ability for a primary treatment to be installed in the future.

Introduction

In February 2014, VicRoads approved a decision to 'step up' and make stronger inroads into road safety. The Safe System approach is the focus of this 'step up'. However, it eventuated that at an operational level there was a need to provide further guidance on the constituents of the Safe System and how to integrate it into the day-to-day decisions about planning, designing, improving, maintaining and operating the Victorian road network.

There is work being undertaken at an Austroads level to integrate Safe System principles into the Road Safety Audit syllabus (ST1774). There is also a project SS1958: Development of a Safe System Assessment Framework for Infrastructure Projects, as well as SS2035: Safe System Infrastructure on Mixed Use Arterials; both of which are multi-year projects.

Safe System Audits/Assessments distinctly 'raise the bar' beyond the work of a Road Safety Audit. A Road Safety Audit qualitatively estimates and reports on potential road safety issues and identifies opportunities for improvements in a traditional safety sense, but does not measure compliance with Safe System principles.

Infrastructure projects currently being approved for construction have varied alignment with Safe System principles. The project team's understanding of how well or poorly their project aligns with Safe System principles varies.

The corollary of these arguments is that a multi-pronged approach is needed to imbed the Safe System into the operations of a State road agency, but in most cases there is no requirement for projects to assess their alignment with Safe System principles.

This paper proposes that, in addition to the encouragement and education currently being undertaken, that State road agencies require an independent audit/assessment of a project's alignment with Safe System principles.

Safe System Audits/Assessments have been used in Western Australia and Victoria, and in Victoria some of the VicRoads Regions (Eastern, South Western and Metro South East) have undertaken Safe System Audits for their projects.

Similar to a Road Safety Audit, there will not be a requirement that the project team accept all recommendations from the Audit/Assessment. However, the process will ensure that the project team has considered the requirements to align with Safe System principles and will be required to justify not meeting Safe System principles.

What is the Safe System?

The Safe System is a road safety philosophy that requires roads to be designed and managed so that death and serious injury are avoidable. The basic principles are:

1. Humans are fallible, and will inevitably make mistakes when driving, riding or walking.
2. Despite this, road trauma should not be accepted as inevitable. No one should be killed or seriously injured on our roads.
3. So, to prevent serious trauma, the road system must be forgiving, so that the forces of collisions do not exceed the limits that the human body can tolerate.

The Safe System is divided into four core interrelated components:

Safer Roads	Safer Speeds
Safer Vehicles	Safer People

What is Safe System Auditing?

Using a specialist, independent and qualified team, Safe System Auditing is the formal safety examination of a road related program, project or initiative. The Safe System Audit can comprehensively assess the safety of:

- an existing road, intersection or length,
- a road investment project, whether at feasibility, design or pre-opening stage,
- a community road safety program or funding application,

Table 1 – Framework for the conduct of a Safe System Audit

Safer Roads	Safer Speeds
The Safer Roads component of the Safe System Audit is similar to a Road Safety Audit, in that it is primarily concerned with the physical aspects of the roadway under investigation. However, a Safe System Audit differs because safe system principles are always at the heart of each investigation. This component pays specific attention to feasibility decisions such as selection of intersection type, and technical details of road and barrier design. Key elements that are examined include: • Protection of vehicle occupants from roadside hazards, • Management of vehicular conflict points and angles (such as at intersections), • The “friendliness” and “compatibility” of roadside furniture in accommodating errant vehicles, • Other roadside features that influence the likelihood or consequence of a crash.	The Safer Speeds component of the Safe System Audit is primarily concerned with the setting of appropriate speed limits in accordance with safe system principles. This is a double edged sword in that speed limits must not contribute to severe trauma in a foreseeable crash. Yet, they need to be credible to most drivers so that their actual travel speeds are in compliance with the limit. Key elements that are examined include: • Setting speed limits to prevent trauma at all times, • Designing the road environment to convey the correct speed environment to drivers at all times, • Perceptual treatments, • Variable speed limit treatments based on time-of-day.

Safer Vehicles	Safer People
The Safer Vehicles component of the Safe System Audit considers the key role vehicles have in achieving a safe system. The contribution of vehicles in a Safe System Audit become significant: • When a particular vehicle type is highly represented on a road, either in crashes or in transport volume, e.g. on a heavy freight route, or a recreational bicycle route, • Over time, when the penetration of vehicle safety features in the fleet impact on other areas of the system, e.g. electronic stability control, or autonomous emergency braking. Safe System Audits are also applicable where policy decisions are being made on whether to support or promote cutting edge vehicle technologies such as autonomous vehicles (self-driving cars).	The Safer People component of the Safe System Audit considers the widest range of issues and measures, including: • Impaired driving (distractions, mobile phones, drugs, alcohol, fatigue), • Restraints wearing (seat belts and child restraints), • Speed choice, • Driver attitude and risk taking, • High risk groups, i.e. children, elderly, disabled, novice road users This part of the process involves local police and community leaders as they assess and attempt to influence the compliance of people with relevant road laws. Community engagement initiatives are scrutinised so that the project has the best chance of success, by gaining strong community acceptance. To obtain the maximum safety benefits from a program, it is critical to achieve and maintain strong community acceptance to any changes as early in the process as possible

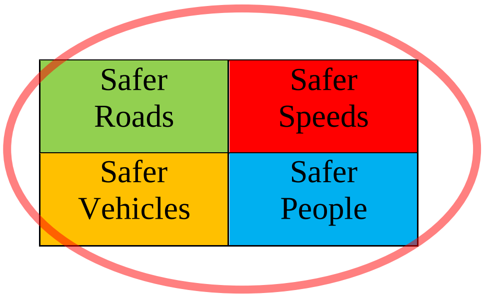
These assessments are carried out considering each of the core components of the Safe System. Table 1 shows how the Safe System Audit is conducted.

A typical consulting company, such as Safe System Solutions Pty Ltd, undertakes two types of Safe System Auditing depending on specific needs:

1. Full Safe System Auditing
2. Road and Roadside Safe System Auditing

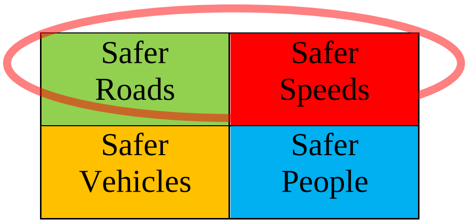
Full Safe System Auditing

Using the framework outlined above, a full Safe System Audit undertakes an in-depth investigation of all four safe system components, including the relevant road and roadside, vehicle safety and people issues. It will provide you with a holistic insight into the performance of a given road, project or programme in relation to Safe System principles.



Roads and Roadside Safe System Auditing

A **Safe System Audit for Roads and Roadside** assesses if and how existing or future roads and roadsides comply with Safe System principles. It focuses on the upper two components in the Safe System diagram, being Safer Roads and Safer Speeds.



A Roads and Roadside Safe System Audit reports its results by categorising the road and roadside treatments and features as:

1. **Primary treatments: Safe System compliant treatments or features;**
2. **Step Towards Safe System compliant treatments or features**;
3. **Safe System supporting treatments or features;** or
4. **Non-Safe System compliant treatments or features**.

The Safe System Audit provides advice on how to raise all road and roadside features into the **Primary treatments** category.

Is a Safe System Audit different to a Road Safety Audit?

The answer to the question posed by the heading of this section is: yes. Road Safety Audits (RSA) are an excellent road safety initiative, but they are not Safe System Audits. A RSA qualitatively estimates and reports on potential road safety issues and identifies opportunities for improvements in safety, but does not measure compliance with Safe System principles.

Consider this simple example. A new project undertakes to install traffic signals at an intersection between two 60 km/h roads. Importantly, an RSA critically looks at the specific components and interactions of features of the design to ensure they don’t create unexpected safety issues. However, the RSA is not designed to address the potential issue of high impact forces at the intersection.

In contrast, a Safe System Audit will address this issue and recommend ways to reduce the kinetic energy transfer rates in crashes to levels that do not result in fatal or serious injuries.

The benefits of a Safe System Audit

A Safe System Audit will provide a system manager with:

- A clear assessment of compliance with Safe System principles.
- Advice on additional measures or changes that will ensure compliance with Safe System principles.
- Independent certification of compliance with Safe System principles.

Safe System Auditing in practice

Safe System Auditing is still an emerging praxis. Safe System Solutions Pty Ltd has undertaken a number of Safe System Audits for VicRoads and the Transport Accident Commission (TAC).

Some of the key points to note for a Safe System Audit are that the audit requires a literature review, desktop study, and on-road examination. It then examines in considerable detail, not shown in this paper, the crash implications (forces) of possible crash types. In addition to intersections, the audit also examines the carriageway, roadsides, and also the implications for pedestrians, cyclists and motorcyclists.

An example of an issue identified in a Safe System Audit is associated with gaps in lengths of wire rope safety barrier (WRSB). The design in Figure 1 below shows a gap between two lengths of WRSB on a road with an 80km/h speed limit. While the run off area in this section is greater than the 'clear zone', it is not a Safe System solution. Research by the Monash University Accident Research Centre (MUARC), the Centre for Automotive Safety Research (CASR) and the Australian Road Research Board (ARRB) show that the concept of a clear zone is not by itself a Safe System solution. The research shows that, on a high speed road, to achieve a Safe System clear zone, it is estimated that a recovery area of more than 30 metres from the edge line would be required. This area would need to be smooth, easily traversable and free from hazards.

Figure 1: Example road design that does not meet Safe System principles

The other non-Safe System feature of the design clip in Figure 1 is the ability for a head on crash to occur at 80km/h (which exceeds what is considered acceptable under a Safe System (70km/h)).

These elements would be identified in a Safe System Audit, with practical advice to the project manager on how to design and install features that align with Safe System principles.

Another example of an issue identified in a Safe System Audit can be seen in Figure 2 below. An at-grade intersection in an 80km/h speed zone. While controlled by traffic signals, the energy associated with a crash at these angles and speeds far exceeds those accepted as 'Safe System'. The Safe System Audit undertaken for this intersection used the Kinetic Energy Management Model (KEMM) produced by MUARC in 2010 to determine acceptable speeds to align with Safe System principles. The summary table from the KEMM can be seen in Table 2 below.

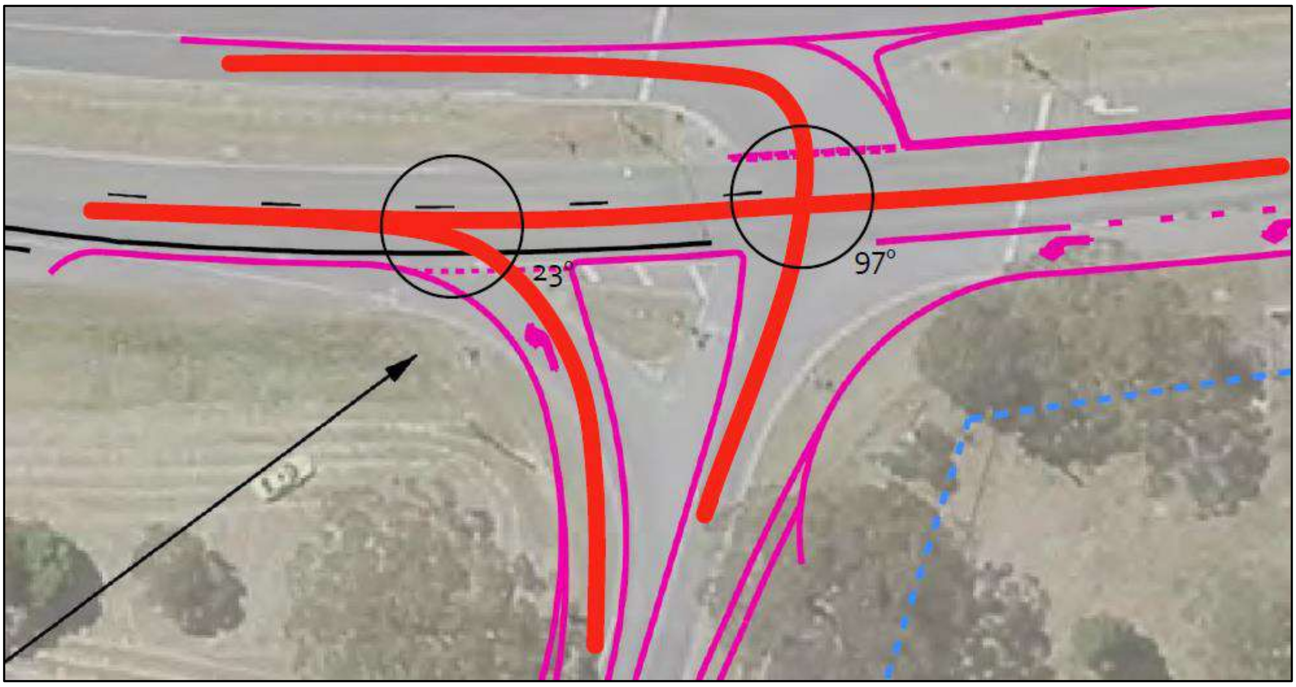


Figure 2: Example an intersection that does not meet Safe System principles

Table 2: MUARC 2010, Acceptable speeds and angles to achieve Safe System for vehicle to vehicle collisions.

Maximum impact speed (km/h)	Maximum acceptable conflict angle
40 and below	All OK
50	90°
60	52°/128° (from KEMM-X)
70	0°/180°
80 and above	None feasible

NOTE: 0° and 180° in the above table indicate a head-on and rear-end collision respectively.

Conclusion

Safe System Auditing can play a useful role in improving safety outcomes on roads and roadsides. It forms a useful supplement to Road Safety Auditing and it is expected that, in the long term, Road Safety Audits will be superseded by Safe System Audits for infrastructure projects. Thus, in the short to medium term, there exists a requirement to train practitioners on the fundamentals and process of Safe System Audits/Assessments. This will expand the pool of Safe System Auditors and continue to imbed Safe System principles into the industry.

Driver views on safety at roadworks

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Abstract

Poor compliance with temporary speed limits is a common contributing factor in roadway work zone crashes. Despite the wide range of measures used to encourage compliance, speeding remains a major challenge in work zone traffic control. As part of the major study into safety at Queensland roadworks conducted by CARRS-Q and industry partners, an online survey was conducted to study the perceptions and experiences of drivers regarding roadworks, speed choice and related safety concerns. Survey participants (N=410) were asked to view photographs of 12 roadwork sites (shot from a drivers' perspective without revealing the speed limits), to nominate the speed they thought they would drive at through work zones, and to rate from 1 to 5 separate levels of perceived risk to workers and to their own vehicles. The survey sought further information on topics including recall and effectiveness of public safety messages, perceived effectiveness of common roadwork safety measures, and demographic characteristics. Participants were also invited to express their concerns regarding any general or specific issue related to driving through roadworks. The current paper provides a descriptive summary of key findings from the survey, drawn from preliminary analyses of both quantitative and qualitative data, demonstrating the depth of data and its value for improving knowledge on driver perceptions and speed choice at roadworks. The survey is the first study of driver perceptions of roadwork risks and hazards to include an assessment of self-nominated speeds which can be compared with actual observed speeds at the same roadwork sites.

Introduction

Poor compliance with temporary reduced speed limits is a prominent factor in crashes at roadworks (Debnath, Blackman, & Haworth, 2014a, 2015). Other notable factors include inattentive and distracted driving and disregarding traffic controls, all of which can occur in the context of speeding as well as independently. Research on driving behaviour, speed limit compliance, and the effect of roadwork safety measures draws heavily on historical crash data analyses and observational studies. This provides an essential and logical starting point for description of the roadworks safety problem, but there are important limitations to these approaches. Specifically, crash data analyses and observational studies generally provide only limited insight into the underlying reasons for observed events and behaviours (with some exceptions such as identification of impaired driving, for example). In the case of speeding, while the behaviour can often be identified and linked to crash causation, drivers' motivations to speed have not been thoroughly examined. One finding in the literature is that roadwork speed limits do not always seem credible: drivers will often react to seeing workers but may not react to signage alone. In the current study, the *Driver Experience of Roadwork Survey* was conducted to enhance our understanding drivers' behaviour by examining their perceptions, beliefs and experiences regarding roadway work zones.

Method

Survey aims and design

The aims of the survey were to (1) identify factors influencing choice of speed through worksites, (2) examine participants' assessment of risk to their vehicles and to workers, and (3) examine the influence and effectiveness of a range of safety measures.

In survey section 1, participants viewed randomly ordered photographs of 12 scenarios taken from a driver's perspective at 9 different worksites (Appendices, Figure 1). The photographs depicted various roadway and worksite characteristics, including highways, arterial and minor suburban roads, day and night works, dry and wet conditions, and varied alignments. To allow them to place the roadwork scenarios within a broader driving context, participants were informed about the general roadway characteristics including the number of lanes, divided or undivided, rural or urban, and whether it was a suburban road/highway/motorway. Some scenarios included workers and/or machinery in the foreground or middle ground while others depicted little or no apparent activity. All scenarios operated under reduced speed limits, from 20 km/h to 60 km/h, which were not revealed to participants. Participants nominated the speed they thought they would drive at through each worksite and also rated on scales of 1 to 5 the perceived likelihood of damage to their vehicle and injury to a worker.

Section 2 examined the influence on speed choice of 12 work zone items which were later classified into four categories: Regulatory/enforcement; Informational; Visibility/conspicuity; and Physical. These categories drew on work by Debnath, Blackman and Haworth (2012) in which most of these items have previously been discussed in similar groupings. Participants answered the question ('how likely are the following items to affect your speed at roadworks?') on a five point scale for each item in random order. The 12 items were selected based on relevance to the local context and the literature. Items were deemed locally relevant if used in Queensland work zones or if drivers could be expected to be familiar with their use in another context (increased fines or demerit points during holiday periods, for example). Following section 2, participants were invited to 'comment on any aspect of roadwork safety that you feel is important and is not covered in the survey'.

The final survey section sought demographic information on participant characteristics, providing the ability to control for those characteristics in statistical analyses, and an indication of sample representativeness.

Participation

Recruitment

The survey was administered online for 17 weeks commencing 8 October 2013. Selection criteria sought Queensland residents with a current driver licence who drove at least weekly and had not been employed in roadworks/traffic control. Participants were recruited through advertising on the CARRS-Q website, group email distribution, media coverage and snowballing techniques. Participants were also recruited through the CARRS-Q InSPiRS research panel (Independent Survey Panel in Road Safety), consisting of 850 members of the public who had agreed to participate in CARSS-Q research. Of these, 373 panellists who met the survey selection criteria were invited to participate.

Participant characteristics

The survey was completed by 410 participants, including 99 InSPiRS panel members and 311 members of the general public. Participant characteristics are presented in Appendices, Table 1. The overall sample suggests that younger drivers (17-24 years) were slightly underrepresented compared to Queensland licence holders, balanced by a slight overrepresentation of drivers aged 25-59 years. Geographically, in terms of Australian remoteness categories the sample was distributed fairly evenly compared with Queensland's population (Outer regional participants were slightly overrepresented). The sample was less representative in terms of household income and occupancy; compared with ABS census data, higher income households and two-person households were overrepresented, while low income and single person households were underrepresented. The characteristics of panel versus non-panel participants differed significantly on several variables including age, gender, household size and income. The sub-samples were thus biased although when combined the overall sample was more representative of the Queensland population.

Results

Mean nominated speeds and compliance rates for the 12 roadwork scenarios are presented in Appendices, Table 2. Male participants nominated significantly higher mean speeds than females for 8 of the 12 scenarios. For 4 of the 12 scenarios, younger participants nominated higher speeds while older participants nominated lower speeds compared to those aged 25-59 years. Mean nominated speeds also differed according to panel membership for 3 scenarios, with non-panel participants tending to nominate slightly higher speeds. Reflecting to a large extent the mean nominated speeds, compliance rates were generally lower for scenarios with lower speed limits. Mean ratings of the likelihood of damage to (a) participants' vehicle and (b) injury to a worker are shown in Appendices, Table 3. Responses on average suggest that vehicle damage and worker injury were considered similarly unlikely. While younger participants and males appeared slightly more optimistic on these measures the differences were not statistically significant.

Approximately 71% (n=288) of participants recalled seeing or hearing a public awareness or education campaign about roadworks in the previous five years. Television was the most commonly reported delivery mode (67.0%), followed by radio (14.9%), billboard (8.7%) and newspaper (5.6%). In terms of perceived effectiveness, most participants reported that the recalled message was somewhat effective (53.8%) or very effective (14.9%) in making them think about safety around roadworks. About two thirds (65.6%, n=189) reported that the message actually influenced their driving at roadworks. Of those, the message caused them to pay more attention (33.3%), drive slower (15.9%), or both (48.1%).

The likelihood of 12 different work zone items to effect participants' speed choice has been previously reported (Blackman, Debnath, & Haworth, 2014a), showing that the visible presence of workers and/or police was significantly more likely to encourage compliance than any other item, including the threat of enforcement and increased penalties. This finding is consistent with the literature, particularly regarding police presence as a highly effective speed reduction measure. The finding on the influence of visible work activity (Blackman, Debnath, & Haworth, 2014b) was strongly supported by comparison of two (60 km/h) scenarios in which the presence or absence of activity was the only clearly discernible difference; significantly lower speeds were nominated for the 'activity' scenario (41.7km/h) compared with the 'no activity' scenario (53.5 km/h), a pattern that persisted irrespective of age, gender or panel membership.

The invitation to comment on 'any aspect of roadwork safety that you feel is important and is not covered in the survey' was useful in raising issues important to drivers which may not be prominent in the literature. As reported in Blackman et al. (2014b), the apparent lack of work activity frequently encountered by drivers at roadworks was thought to encourage complacency and disregard for reduced speed limits. Of those who commented on any issue (N=206), 56% raised concerns about this apparent phenomenon. Encouragingly, the need to address this problem has been formally recognised in Queensland (TMR, 2014), with the road authority promoting action to improve the credibility of roadwork speed limits. There was some explicit recognition that hazards may remain at vacant sites, however this was very limited. Among a range of other concerns raised by participants were calls for education and awareness campaigns, including from those who themselves appeared to misunderstand some traffic control measures:

> *Public doesn't understand that when the worker plate on a roadworks speed sign is missing, it means that no one is on site, and the last speed sign is still active, e.g. 80km/h through roadworks on a Sunday, hit a 60km/h sign with no worker plate in it, it is still 80km/hr. There is no public awareness with this rule… people slow down creating hazards*

On the strength of this and other comments, further efforts to improve drivers' knowledge and awareness may indeed be warranted, though traditional education campaign formats may have only limited impact (Debnath et al., 2012, 2014b).

Main limitations of the study include the potential for self-report bias in survey responses, the potential for participants to misinterpret some aspects of the scenarios presented as still images, and an underrepresentation of Queensland's youngest drivers in the survey sample.

Conclusion

The *Driver Experience of Roadwork Survey* was the first of its kind in Australia to examine driver perceptions around safety at roadworks including factors influencing speed choice. Quantitative data was supplemented with qualitative material in the form of open-ended comments, enabling a deeper, more meaningful interpretation than would have been possible with quantitative material alone. In terms of practical implications, the study supports recent moves by authorities to improve roadwork speed limit credibility, while also highlighting the ongoing need to improve driver awareness. While this paper has presented a descriptive analysis, further analyses are to be conducted examining speed choice and its relationship with multiple environmental and driver factors in the 12 survey scenarios.

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Appendices

Figure 1. 12 scenarios in Driver Experience of Roadwork Survey

Table 1. Driver Experience of Roadwork survey participant characteristics

Characteristic	**Non-Panel** N	%	**Panel** N	%	**All** N	%		
							QLD Licence holders (2013)	
Age 17-24	23	7.5	-	0.0	23	5.7	396751	12.03
25-59	248	81.3	40	40.8	288	71.5	2142293	64.96
60>	34	11.1	58	59.2	92	22.8	758614	23.01
Pearson Chi Sq sig	<0.001							
17-20	3	1.0	-	0.0	3	0.7	169968	5.15
21-24	20	6.6	-	0.0	20	5.0	226783	6.88
25-29	48	15.7	-	0.0	48	11.9	307302	9.32
30-39	79	25.9	4	4.1	83	20.6	616463	18.69
40-49	64	21.0	9	9.2	73	18.1	641107	19.44
50-59	57	18.7	27	27.6	84	20.8	577421	17.51
60-74	34	11.1	52	53.1	86	21.3	589856	17.89
75>	-	0.0	6	6.1	6	1.5	168758	5.12
Valid total	305	99.9	98	100.0	403	100.0	3297658	100.0
Missing	6		1		7			
Gender								
Male	174	56.9	44	44.4	218	53.8	1734354	51.4
Female	132	43.1	55	55.6	187	46.2	1640470	48.6
Valid total	306	100.0	99	100.0	405	100.0	3374824	100.0
Missing	5		-		5			
Pearson Chi Sq sig	0.031							
ASGS location							**QLD ERP (2012)**	
RA1 - Major Cities	NA		NA		149	57.6	2824102	61.9
RA2 - Inner Regional					47	18.1	923908	20.3
RA3 - Outer Regional					58	22.4	672561	14.7
RA4 - Remote					5	1.9	79900	1.8
RA5 - Very Remote					-	0.0	59588	1.3
Valid Total					259	100.0	4560059	100.0
Unknown					151			
Household Income (wk)*							**ABS census (2011)**	
Up to 29,999 (<577)	10	3.6	14	18.2	24	6.8	323813	22.96
30,000 – 49,999 (577-961)	20	7.3	11	14.3	31	8.8	265694	18.84
50,000 – 79,999 (962-1538)	54	19.7	15	19.5	69	19.7	246137	17.45
80k – 99,999 (1539-1923)	49	17.9	13	16.9	62	17.7	182880	12.96
100k – 149,999(1924-2885)	68	24.8	19	24.7	87	24.8	249975	17.72
150,000 or more (>2885)	73	26.6	5	6.5	78	22.2	142048	10.07
Valid total	274	100.0	77	100.0	351	100.0	1410547	100.0
Unknown/missing	37		22		59			
Pearson Chi Sq sig	<0.001							
Household occupants**							**ABS census (2011)**	
1	25	8.3	17	17.2	42	10.4	353560	22.8
2	127	41.9	62	62.8	189	47.0	551518	35.6
3	56	18.5	9	9.1	65	16.2	249508	16.1
4	69	22.8	9	9.1	78	19.4	236221	15.3
5	20	6.6	2	2.0	22	5.5	102980	6.7
6	6	2.0	-	0.0	6	1.5	53592	3.5
Valid total	303	100.0	99	100.0	402	100.0	1547379	100.0
Missing	8		-		8			
Pearson Chi Sq sig	<0.001							

*Income data sourced from http://profile.id.com.au/australia/household-income?WebID=120 NB: ABS income category ranges do not match exactly those used in survey. Collapsed into 6 categories of weekly income, they are: Up to $599; $600-$999; $1000-1499; $1500-1999; $2000-2999; $3000>

**Census household data sourced from http://profile.id.com.au/australia/household-size?WebID=120

ASGS = Australian Statistical Geography Standard. ERP = Estimated resident population.

Table 2. Mean nominated speeds and compliance rates for roadwork scenarios*

	Scenario											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Speed limit km/h	***60***	***40***	***40***	***60***	***40***	***60***	***40***	***40***	***20***	***40***	***40***	***60***
Mean speed	57.73	42.14	53.34	41.25	36.14	41.73	43.13	40.39	34.82	39.85	42.95	53.53
Non-panel	58.8	42.68	54.09	41.88	36.09	41.67	43.53	40.63	34.92	39.33	43.28	54.42
Panel	54.39	40.45	51.01	39.29	36.31	41.92	41.87	39.65	34.49	41.46	41.92	50.76
t-test sig**	.011	NS	NS	.039	NS	NS	NS	NS	NS	NS	NS	.035
17-24	63.70	45.87	58.26	43.70	36.30	44.13	46.52	43.48	37.17	39.78	47.61	55.65
25-59	58.44	42.81	54.48	41.49	35.89	41.55	43.52	40.94	34.72	39.77	43.36	54.06
60>	53.15	38.97	48.32	39.40	35.98	41.36	40.98	37.72	34.57	39.46	40.27	51.03
Oneway sig	0.001	0.003	0.001	NS	NS	NS	NS	0.027	NS	NS	0.003	NS
Male	59.79	43.37	54.08	42.32	37.50	42.22	44.38	40.60	35.05	41.24	44.04	54.93
Female	55.13	40.67	52.43	39.97	34.36	41.02	41.76	40.11	34.63	38.13	41.60	51.71
t-test sig**	.002	.014	NS	.030	.009	NS	.022	NS	NS	.037	.018	.032
Compliant %	78.1	72.5	37.4	98.0	85.3	97.5	67.6	77.4	16.7	71.9	71.5	85.5
Non-panel	75.3	71.4	36.5	98.1	85.4	97.4	67.6	76.9	17.2	73.6	71.8	84.1
Panel	86.9	75.8	40.4	98.0	84.8	98.0	67.7	78.8	15.2	66.7	70.7	89.9
Chi Sq sig	0.016	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS
17-24	73.9	56.5	13.0	100.0	87.0	100.0	56.5	69.6	8.7	78.3	47.8	82.6
25-59	76.0	71.9	36.5	97.9	86.5	97.6	68.1	76.4	17.4	73.6	71.9	84.7
60>	88.0	79.3	47.8	98.9	84.8	96.7	70.7	83.7	16.3	67.4	78.3	89.1
Chi Sq sig	0.043	NS	0.006	NS	NS	NS	NS	NS	NS	NS	0.015	NS
Male	74.3	65.1	35.3	97.2	82.6	96.8	63.3	74.8	15.1	69.3	67.0	83.0
Female	82.9	81.3	40.1	98.9	89.3	98.4	72.7	80.7	18.2	75.4	77.5	88.8
Chi Sq sig	0.037	0.001	NS	NS	0.054	NS	0.043	NS	NS	NS	0.018	NS

*Actual speed limits were not revealed to participants. **Equal variances assumed

Table 3. Reported likelihood of vehicle damage/worker injury while driving through roadworks*

	Scenario											
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
Speed Limit	***60***	***40***	***40***	***60***	***40***	***60***	***40***	***40***	***20***	***40***	***40***	***60***
Likely damage**	1.88	2.08	2.02	2.23	2.43	2.90	2.00	2.64	2.09	2.60	1.81	2.38
Non-panel	1.88	2.06	2.00	2.22	2.44	2.95	2.02	2.69	2.08	2.61	1.81	2.39
Panel	1.90	2.11	2.09	2.25	2.39	2.74	1.95	2.52	2.13	2.56	1.80	2.32
17-24	1.83	1.91	1.96	2.26	2.22	2.74	1.83	2.48	2.09	2.70	1.65	1.96
25-59	1.91	2.11	2.01	2.27	2.49	3.03	2.02	2.68	2.09	2.65	1.83	2.47
60>	1.78	2.00	2.04	2.07	2.30	2.50	1.95	2.55	2.09	2.39	1.77	2.18
Male	1.77	1.90	1.94	2.10	2.26	2.70	1.89	2.53	2.00	2.40	1.69	2.26
Female	2.01	2.28	2.12	2.37	2.63	3.12	2.12	2.78	2.19	2.82	1.95	2.51
Likely injury**	1.90	2.18	2.79	2.32	2.26	2.62	2.43	2.27	2.51	2.24	2.25	1.87
Non-panel	1.90	2.19	2.84	2.30	2.30	2.66	2.45	2.29	2.52	2.25	2.28	1.87
Panel	1.90	2.16	2.62	2.40	2.15	2.51	2.36	2.22	2.46	2.22	2.15	1.87
17-24	1.74	1.87	2.74	2.13	1.96	2.57	2.26	2.09	2.35	2.04	2.04	1.52
25-59	1.92	2.25	2.87	2.35	2.35	2.69	2.46	2.31	2.54	2.32	2.29	1.92
60>	1.85	2.03	2.53	2.27	2.09	2.39	2.35	2.18	2.41	2.05	2.13	1.82
Male	1.75	1.99	2.58	2.12	2.03	2.43	2.24	2.09	2.36	2.01	2.04	1.78
Female	2.07	2.41	3.03	2.56	2.54	2.83	2.64	2.48	2.68	2.52	2.48	1.99

*Rated 1 (Highly unlikely) to 5 (Highly likely); **t-test = Not statistically significant (NS)

Motorcycle clothing fabric burst failure during high speed impact with an abrasive surface

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Abstract

High energy is involved when a rider impacts a road surface in a crash. Rider speed, height of fall and road surface morphology all contribute to the level of initial impact energy. Impact can cause fabrics and seams of protective garments to burst rendering their protective value void. The Cambridge abrasion tester tests protective clothing with a fall height of 50mm and abrasive belt speed of 28km/hr, far below what can happen in a "high side" motorcycle crash at 100km/hr. This work addresses the mechanics of what occurs in the first few microseconds of an impact and provides insight into the effect that speed has on fabric burst.

This work used a Cambridge impact abrasion test to evaluate two different protective motorcycle clothing fabrics (a denim and brushed fleecy fabric over a p-aramid protective liner). It measured their abrasion resistance at an abrasion speed of 28km/hr and standard impact height. It used a high speed camera to measure the impact displacement of the test head.

Fabrics with high stretch were more prone to burst failure on initial impact. Fabric burst is caused by a high speed tensile stress between the fabric coupled with the abrasion surface and the inertia of the body dragging against it. Stretch fabrics are pushed into the abrasion surface for a longer period by the body before the tensile stress occurs so the coupling force is higher. If the transition to abrasion occurs early in the impact then a fabric is less likely to burst.

Introduction

European studies have shown that 75% of motorcycle crashes happen at or below 50km/hr (ACEM, 2004). A large number of the injuries sustained are grazing or gravel rash from sliding or rolling along the ground (de Rome, 2006). The use of effective personal protective clothing has been shown to reduce motorcycle injury cost and with effective design can be used to reduce the severity of motorcycle injuries (de Rome et al., 2011). Previous work has shown the method of construction fabric thickness and fibre type have a significant impact on the abrasion resistance of protective apparel fabrics (Hurren, Phillips, & Wang, 2014).

The most accepted method for measuring resistance to abrasion in a motorcycle fabric is by the Cambridge type impact abrasion testing (Hurren et al., 2014; Woods, 1996a). Impact abrasion testing has had correlation with simulated and emergency department accident damage (Woods, 1996b) and is the test method used by the CE standard accreditation of motorcycle clothing (EN 13634:2010). Burst and subsequent instant failure of some fabrics has often been observed when they contact with the abrasion belt. Fabric burst is not unusual and has been observed in many accident situations however the reasons for fabric burst during impact abrasion testing warrants further investigation

This study has used a high speed camera to understand the mechanics of impact that occur when a fabric coated surface is dropped onto a 60 grit sand paper surface. It proposes a hypothesis for burst failure due to impact mechanism and this may be used to design safer motorcycle clothing.

Method

The fabrics used in this research where a 400g/m^2 woven cotton denim and a 380g/m^2 knitted polyester/cotton brushed fleecy fabric in combination with a 440g/m^2 loop knitted p-aramid protective liner.

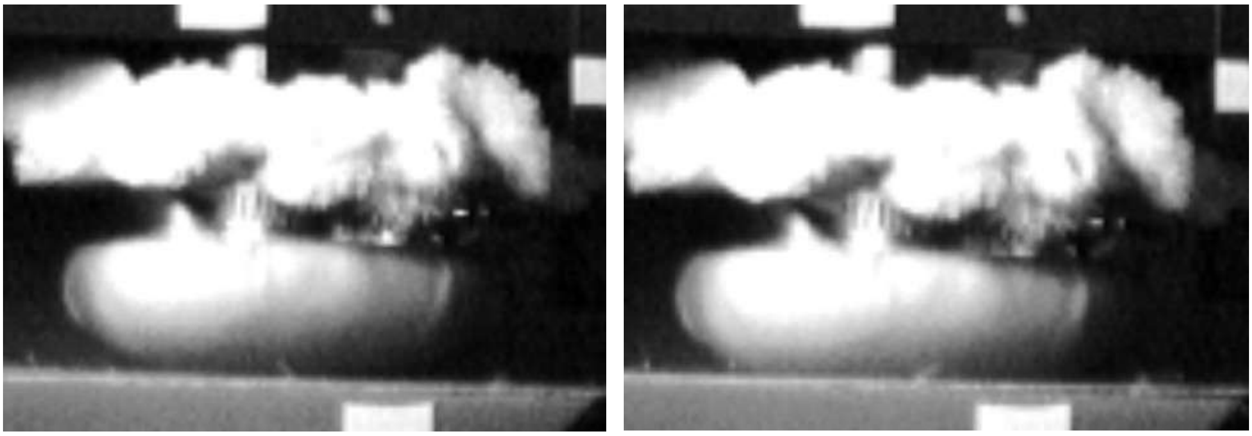
Impact abrasion testing was conducted on a Cambridge style impact abrasion tester (Mesdan laboratories, Italy) according to EN13595-1. Samples were cut into 160mm diameter and clamped to the test head using a spiral lock clamp. The samples were placed so that they had an outer denim fabric and internal abrasion resistant fabric. Six test samples were conducted for each fabric type.

For high speed camera measurement the fabrics were placed on the abrasion head and then dropped onto the test belt from 50mm with the test belt off. High speed images at 2000 frames per second were captured using a MotionScope PCI 2000S monochromatic camera (Redlake, Germany). Lighting was provided by two 500W quartz halogen stand lights. The displacement of the test head was measured using the distance between the top left hand corner of the white reference marker on the sample mounting frame (right hand side of abrasion sample) and the same reference point on the white marker below the abrasion sample. High speed camera images were used to create the displacement versus time curve to understand the gripping forces operating on the fabric.

Stretch and elongation at break tests were performed on a 5967 Materials Testing System (Instron Corporation, USA) equipped with a 1000 N load cell. The test gauge length was 100mm with samples frayed to have a 50mm width and 5mm frayed edge on each side. Both breaking force and elongation at break were conducted at 100mm/min extension rate. Five samples of the warp and weft were measured for each fabric type.

Results and Discussion

The time from the point of first contact with the abrasion surface to point of maximum force being applied to the fabric against the abrasion surface is dependant on the thickness and compressability of the fabric, the impact mass and the height of impact. In these initial experiments the impact height and mass were kept constant and only the fabric varied. Figure 1 shows the images of impact for a denim fabric covering two protective loop knitted aramid layers. The first image (a) is the point where the fabric first engages with the abrasion belt and the second image (b) is taken 6.5ms later at maximum downward displacement of the impact surface.



(a) (b)

Figure 1. Abrasion sample in initial contact (a) and at maximum downward displacement (b)

Analysis of these high speed images produced a displacement versus time curve that enabled a better understanding of the dynamics occuring in the impact (figure 2). As the sample impacts the surface the force pushing the fabric into the surface increases to a maximum point before reducing again as the body bounces off the surface. There was some hysterisis then observed with a second fabric compression before coming to equilibriam at a final compression level. The maximum downward displacement and subsequent impact force was achieved in the initial impact displacement. For burst to occur the fabric must grip with the abrasion surface and a tensile force is then applied between the clamp and the abrasion surface. Once slip of the fabric on the abrasion surface occurs the tensile force applied is significantly reduced. The point of change from grip to slip is then very important for the burst resistance of a fabric.

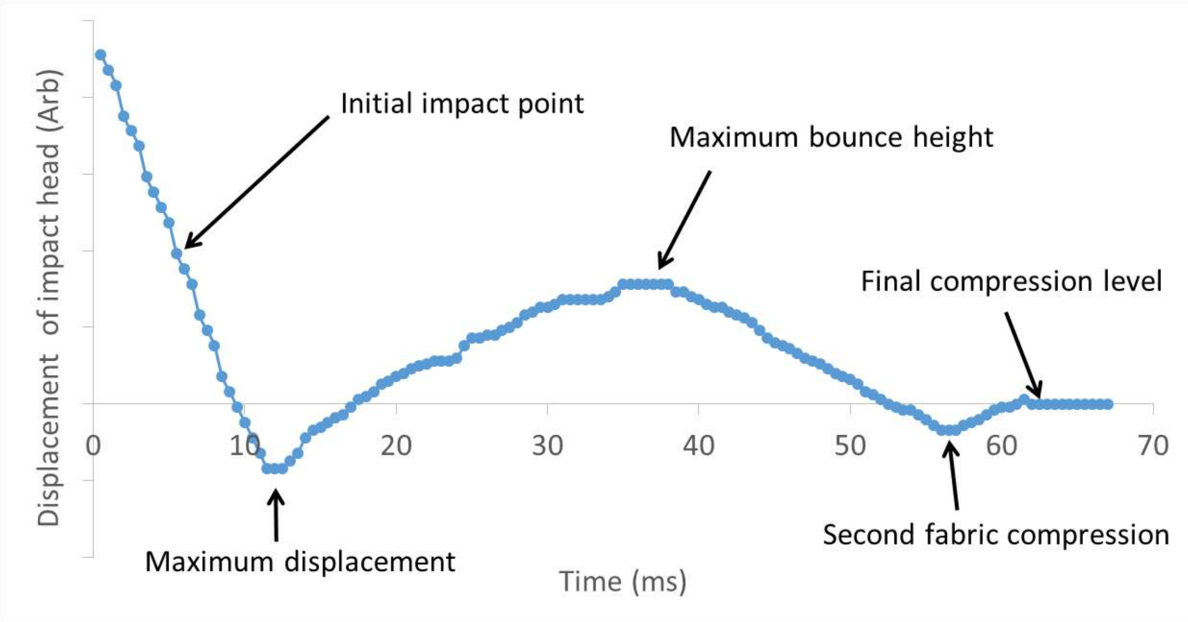


Figure 2. Impact displacement curve for stationary abrasion belt

To understand the mechanism of burst, the stretch of the fabric must be considered as this will alter the point of grip to slip transition. The stretch of a low stretch denim fabric was 20% at break. The gauge length of the abrasion tester was 30mm between the test head and the impact surface. There would need to be greater than 6mm extension of fabric when impacting with the moving belt for burst to occur in the test setup. At 8m/s (28.8km/hr) abrasion surface speed it would require the fabric to be in contact with the abrasion surface for 0.75ms before it would extend 6mm (maximum extension). If the transition from grip to slip has not occurred by this displacement then burst will occur. When this transition to abrasion time was placed on the impact displacement curve (figure 3) the amount of grip force would be low as the impact pressure is only slightly acting on griping the fabric with the abrasion surface. With a low gripping force the fabric would be expected to transition from grip to slip without bursting (as observed in abrasion trials). If the speed was increased to 28m/s (100.8km/hr) the gripping force would reduce making burst on impact less likely. If the speed is reduced then the gripping force is increased contrary to common belief.

With the protective hoodie fabric the extension was 130% at break. The impact displacement curve for the protective hoodie was similar to that of the protective denim so only the protective denim curve was used to explain the findings. There would need to be 39mm extension of fabric for burst to occur. At 8m/s belt speed it would take 4.9ms for the fabric to extend this distance before it went from grip to slip. This would result in a significantly higher grip level occurring before the change from grip to slip could occur. The grip with the abrasion surface could be high enough to enable a tensile failure to occur in the fabric (for this fabric burst was observed in abrasion testing). At 4m/s (14.4km/hr) the impact force was reducing as the body had bounced on impact but burst was still observed.

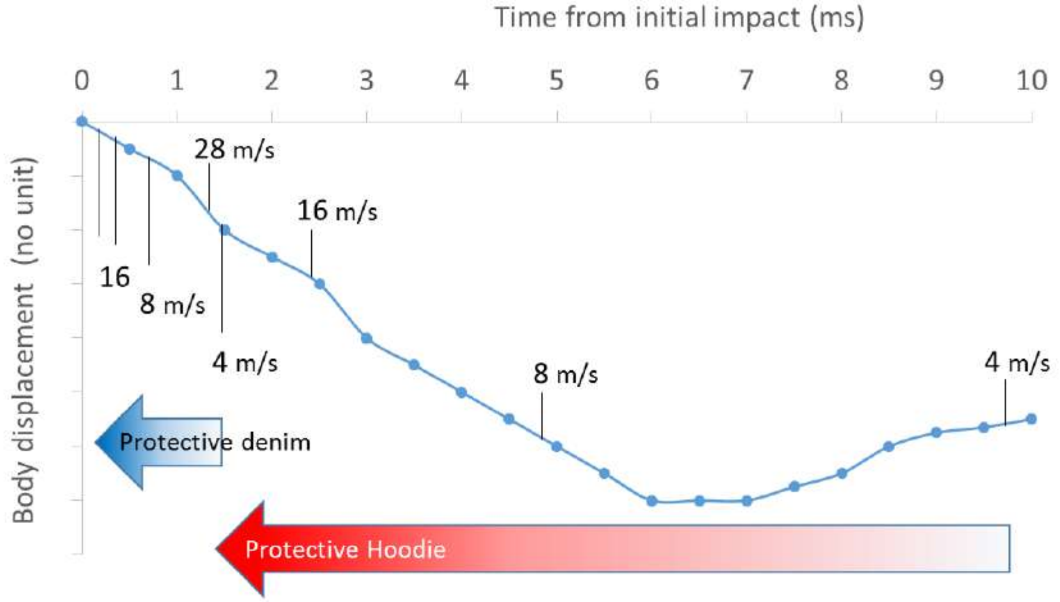


Figure 3. Impact displacement curve with maximum extension before burst points highlighted for protective hoddie (above the line) and protective denim (below the line)

Conclusions

The force applied to a fabric during impact abrasion is dependent on the abrasion surface speed, impact height and weight. For burst to occur the fabric must be pushed into the abrasion surface to provide an effective grip to enable tensile forces high enough to cause tensile failure (burst). The level of stretch of the fabric allows it to extend the time before high tensile loading into a region of maximum grip with the abrasion surface. High stretch fabrics need to have higher fabric strengths to resist burst or they will be prone to burst on impact. Lower speed impacts with an abrasion surface are more likely to induce burst failure than high speed impacts. Further impact abrasion testing at different abrasion surface speeds is still required to confirm this hypothesis. These results will be important in the design of burst resistant protective fabrics for both motorcyclists and bicyclists.

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Accommodation of low birth weight babies in dedicated and convertible rearward facing child restraint systems

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Introduction

Child restraint systems (CRS), are designed to protect a child from injury in a motor vehicle collision. While the use of any restraint is better than no restraint, the best crash protection is provided when the child uses a restraint that is appropriate for the size of the child and the restraint is correctly fitted (to both the vehicle and the child). (Brown et al., 2006; Brown and Bilston, 2007). Current infant restraint systems are designed to fit babies of normal birth-weight; however some babies are discharged from hospital at just over half of this weight. Almost 20% of babies discharged from the special care nursery at one Sydney hospital are < 2.2kg. While it is likely that these lower birth weight (LBW) infants may be poorly accommodated in many child restraints on the market, this has not been studied previously.

All child restraints sold in Australia must comply with the requirements of Australian/New Zealand Standard 1754. Guidelines for the provision of restraints designed for low birth weight babies were recently included in AS/NZ1754 (AS, 2013).. These guidelines were developed based on anthropometric data and there has been no study of the real world fit of LBW infants in restraints complying with these guidelines.

This study aimed to examine the quality of accommodation provided to new born infants by child restraint systems, and specifically the accommodation provided to low birth weight infants.

Method

A cohort of 90 new born infants (median weight 2.4kg) within 1 week of discharge was recruited from the postnatal ward and special care nursery of a Sydney hospital from July 2012 to August 2014. Inclusion criteria required the infants to be within one week of scheduled discharge. Informed consent was obtained from the infant's parent. The study was approved by the North Shore Local Health District Human Research Ethics Committee.

The infants were placed in a selection of 4 infant restraints (2 dedicated and 2 convertible rearward facing restraints). A subset of infants was then also placed in a restraint designed to meet the LBW restraint design requirements of AS1754. Once the child was placed in the restraint, the harness was adjusted to fit the baby and a series of photographs of the baby in the harness were taken. Accommodation was assessed by examining quality of harness fit.The quality of fit of the harness was scored using a 4-point scoring system for 4 different harness fit criteria: buckle position, crotch strap position, shoulder strap height and shoulder strap width As detailed in Table 1, scores from 1-4 were awarded for each criteria based on the correctness of harness fit. These scores were then collapsed into categories of "good" (scores of 3 or 4, indicating a snug and correctly positioned harness) or "poor" (scores of 1 or 2, indicating non-contact between the harness and the infant).

This collapsed scale was then used to assign a rating for overall harness fit, where a "poor" overall fit was assigned if the harness received a "poor" rating for *any* of the four categories of harness fit, or a "good" overall fit was assigned if the harness received "good" scores for *all* four categories of harness fit (Table 1). The quality of fit of the harness was scored from the photographs by a single researcher A second researcher used the same scoring system for 10 randomly selected restraints, and reliability between assessors was examined using intraclass correlations (ICC) calculated using two-way mixed effects models for absolute agreement. This demonstrated moderate to good agreement (ICC 0.61–0.80 good, 0.41–0.60 moderate) between assesses and the reliability of the assessment method.

Harness scores were compared between restraint types and between babies weighing ≤2.5kg and >2.5kg using McNemars test. The relationship between weight and harness fit was explored using linear regression.

Table 1: Harness fit scoring criteria

Score	1	2	3	4
Shoulder strap height	Above top of ear	Between top and bottom of ear	Between shoulder and bottom of ear	At or (just) below shoulder (near jaw / mouth)
Should strap placement	At least one entirely off edge of shoulder	At least one on edge of shoulder	At least one medial or lateral of mid-shoulder but still on shoulder	Both on middle of clavicle
Buckle position	High on abdomen or chest	Bottom of buckle plastic is above but near the top of thighs	Buckle sits slightly high or low on pelvis AND/OR leg straps encroaches on thighs	Buckle directly over middle of pelvis and leg straps not enchroaching on thighs
Crotch strap gap (between crotch strap anchorage and nappy/clothing)	Wider than ~20mm or one thumb width	Between ~20mm and ~5mm	<~5mm	At or under clothing

Results

Results of the harness fit assessments are given in Table 2.

Table 2: Percentage of infants demonstrated poor harness fit by restraint and weight split

Harness score type	Restraint Number (split by infant weight of 2.5kg)								
	Restraint 1 Convert RF/FF*		Restraint 2 Convert RF/FF*		Restraint 3 Dedicated RF**		Restraint 4 Dedicated RF**		Restraint 5 LBW**
	≤2.5kg	>2.5kg	≤2.5kg	>2.5kg	≤2.5kg	>2.5kg	≤2.5kg	>2.5kg	≤2.5kg
Shoulder strap height	17%	6%	26%	0%	20%	7%	44%	27%	0%
Should strap width	47%	33%	65%	50%	24%	17%	17%	6%	13%

Buckle position on pelvis	10%	4%	3%	2%	80%	67%	93%	81%	0%
Crotch strap gap	65%	26%	76%	55%	57%	21%	89%	91%	23%

* RF/FF=Rearward facing/forward facing restraint. ** RF=Rear facing restraint.
***LBW=Restraint was designed to meet requirements for LBW restraint design in AS1754. Only 17 LBW infants were assessed in this restraint (35% of all infants ≤2.5kg in the sample) due to the restraint being unavailable until half way through the study.

The restraint designed for LBW babies provided superior accommodation. Accommodation for LBW infants in the other restraints was generally poor. For LBW infants, harness buckle position was worse in the dedicated restraints than convertible restraints (p=0.03) but shoulder strap width was better in convertible restraints (p=0.04).

A significantly higher proportion of babies had poor buckle position scores in the dedicated rearward facing restraints than convertible restraints (p=0.03) but a significantly higher proportion of babies had poor shoulder strap width in the convertible restraints than dedicated reward facing restraints (p=0.04). There was no clear trend by restraint type for babies achieving poor fit for shoulder strap height and crotch strap gap.

Across all restraints, the scores for shoulder strap height and crotch strap position (gap) were significantly lower (worse) for babies of lower weight (p=0.01 and p=0.03 respectively). The scores for buckle position and the shoulder strap width were not significantly affected by weight.

Discussion

While a newborn will be provided with better protection in a rearward facing restraint of any type, than in no restraint or a different type of restraint, the results of this work demonstrate scope to further improve accommodation of newborn infants in rearward facing restraints. Poor harness scores demonstrates restraint where infants were not adequately accommodated, and the observed poor harness fit involved harnesses that were not in close contact and/or position on the infant's torso. Such poor fit would likely carry an increased risk of ejection in a crash and therefore a reduction in the injury protection provided in a crash. Comparison of infant anthropometry with shoulder and crotch strap geometry in all restraints identified areas for improving AS/NZ1754 (SA, 2013) LBW requirements.

Limitations to keep in mind include the convenience sample, the limited number of restraints examined and the small number of infants observed in the LBW restraint. Others relate to scoring harness fit from photographs but this method was necessary to minimise time infants spent in each restraint.

Despite these limitations, the results indicate parents of LBW infants should be encouraged to use restraints specifically designed to accommodate small infants.

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The Austroads in-depth study of motorcycle crashes in NSW: Causal relationship findings

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Introduction

Motorcyclists represent 16% of fatalities and 22% of serious casualties on Australian roads each year (ATC, 2011), with little change in casualty numbers over the last decade (Transport NSW, 2012). To develop effective countermeasures, there is a need for detailed understanding of risk factors influencing motorcycle crashes. In-depth investigation is the best method for collecting high levels of detail about crashes. The last Australian in-depth study occurred in 1997 (Haworth, 1997) and a number of significant motorcycle interventions have been implemented since that time (e.g., graduated licence schemes, numerous education and awareness campaigns). To identify risk factors for crashes emerging since then, the Australian road and transport agencies commissioned a new in-depth study of motorcycle crashes. The aims of this study were to: 1. Examine causal relationships between human, vehicle, road and other environmental factors and motorcyclists in serious injury crashes, and 2. examine the influence of the total system on the injuries sustained by seriously injured motorcyclists. This paper summarises the causal relationship findings from this study.

Method

To achieve these aims, this study used a case-control in-depth investigation approach coupled with expert multidisciplinary review of crashes. Case riders were motorcyclists aged 16 years or older who were admitted to a study hospital following a crash on a public road between August 2012 and July 2014. Study hospitals included three major trauma hospitals, two in urban Sydney and one in regional NSW. For inclusion, the crash had to have occurred within a four hour drive of Sydney and the rider must have sustained at least one injury that was able to be coded to the Abbreviated Injury Severity Scale (AIS) (AAAM, 2005). Data recruitment and collection followed ANCIS protocols. In short, participating riders were interviewed, their medical records reviewed, and injuries coded to the AIS. The crash scene, motorcycles and equipment used were inspected and photographed, usually within 2 weeks of the crash. Crash scene inspections included a video drive through from both the case and opposing direction perspectives. Collected data was entered into an electronic database, and 4 page summaries of each case were prepared. Case summaries, including the full set of photographs and video drive through were then presented to a multidisciplinary expert review panel. The panel consisted of NeuRA researchers and engineers, a leading trauma forensic pathologist, road engineering and motorcycling experts from the NSW Centre for Road Safety, motorcycle safety research and crash investigation experts and behavioural scientists. Using their combined expertise, the panel identified key contributory factors in each crash and injury outcome using the Haddon Matrix as a framework (Haddon Jr 1972).

Controls were riders who had ridden the same road where the crash occurred but had not crashed at this location. A minimum of one control per crash location was sought but there was no limit placed on the maximum numbers of controls per case. Recruitment occurred via a study website that invited riders to participate and listed sites for which controls were needed. The website was promoted through motorcycle community organisations and the NSW Roads and Maritimes Services website. Riders who registered on-line received a unique link to the control rider survey by email. Riders were also encouraged to visit the web site using study brochures that were attached to parked motorcycles and by advertisements placed in newspapers local to the crash locations. The control survey was completed on-line and consisted of all the questions asked of case riders with the exception of questions about the crash.

The case–control analysis tested the hypothesis that rider and/or trip characteristics will differ between motorcyclists who are involved in a crash at a particular location and those who are not. To test this hypothesis while controlling potential confounders, conditional logistic regression accounting for the 'one:many' control sample design was used to perform the case control analysis. The outcome variable was whether or not the rider belonged to the case or control sample. Due to the large number of potential variables, model building was done in two steps. In Step 1, rider characteristic variables with a significant association ($p<0.05$) with the outcome were used in a backwards stepwise selection procedure as described by Hosmer and Lemeshow (2000) with entry to the model set at $p=0.25$ and exit set at $p=0.15$. Variables remaining in the final model were seen as 'important' rider characteristics and were used in Step 2 of the modelling process. In Step 2, trip characteristic variables with a significant association ($p<0.05$) with the outcome were used together with the 'important' rider characteristics in a second backwards stepwise selection procedure with entry to the model also set at $p=0.25$ and exit set at $p=0.15$. Potential interactions between all variables included in the final model were then explored and the assumption of linearity checked for any remaining continuous variables. Odds ratios and 95% confidence limits for the variables included in the final model were also calculated.

Data generated during the panel reviews and information in the final cases summaries were used to conduct a qualitative analysis of crash and injury causation factors. This involved content analysis conducted by a single researcher in consultation with other investigators achieved by reading and sorting of ideas thematically to describe contributory factors using the Haddon Matrix as a framework. For this analysis, the themes and content generated by this qualitative analysis, relevant to the variables included in the final model generated above were reviewed to provide additional meaning to the quantitative results.

Results

The final case-control sample included 99 crashed riders and 336 control riders. Results from Step 1 and Step 2 of the conditional logistic regression analysis are presented Table 1 and Table 2.

Table 1: Step 1-Final logistic regression model, 'important' rider characteristics (* denotes variables significantly associated with the outcome variable)

Variable	Category	N (%)		Univariate			Multivariate			
		Case	Control	p value	OR	95%CI	p value	OR	95%CI	
Bike Type*	Other	45(46)	266(79)	-			-			
	Sports	53(54)	70 (21)	0.001	4.65	2.58-8.37	0.001	19.73	3.26	119.43
Bike Familiarity*	Very Familiar	63(71)	296(89)	-			-			
	Other	26(29)	37(11)	0.0005	3.32	1.69-6.52	0.038	11.25	1.14	110.91
Off road riding	Yes	36(41)	201(62)	-			-			
	No	52(59)	125(38)	0.021	1.87	1.10-3.19	0.079	4.39	0.84	22.86
Protective Clothing*	*Continuous*	Mean 0.44, SD0.50	Mean 0.83 SD0.37	<0.001	0.45	0.34-0.60	0.002	0.23	0.09	0.59

Table 2: Step 2Final logistic regression model (shading and * denotes variables significantly associated with the outcome variable)

Variable	**Category**	**N (%)**		**Univariate**			**Multivariate**			
		Case	**Control**	**p value**		**95%CI**	**p value**	**OR**	**95%CI**	
Bike Type*	Other	45(46)	266(79)	-			-			
	Sports	53(54)	70 (21)	0.001	4.65	2.58-8.37	0.001	19.70	3.30	119.40
Bike Familiarity*	Very Familiar	63(71)	296(89)	-			-			
	Other	26(29)	37(11)	0.0005	3.32	1.69-6.52	0.004	10.29	2.13	49.66
Age*	*Continuous*	Mean 37.3 SD15.2	Mean 50.1 SD13.9	<0.001	0.95	0.93-0.97	0.001	0.92	0.88	0.97
Protective clothing*	*Continuous*	Mean 0.44, SD0.50	Mean 0.83 SD0.37	<0.001	0.45	0.34-0.60	0.008	0.50	0.30	0.84
Heavy traffic*	No	82(93)	194(58)	-			-			
	Yes	6(7)	142(42)	<0.001	0.05	0.02-0.16	<0.001	0.03	0.004	0.16
Fast but boring*	No	82(93)	237(71)	-			-			
	Yes	6(7)	99(30)	0.0005	0.21	0.08-0.50	0.002	0.08	0.02	0.37
Trip Familiarity*	Other	41(48)	287(89)	-			-			
	Daily	45(52)	34(11)	<0.0001	11.0	4.45-26.94	0.008	5.50	1.55	19.51
Trip Purpose*	Recreation	33(36)	189(59)	-			-			
	Commuting/Transport*	34(37)	69(22)	0.052	2.22	0.99-4.98	0.049	0.19	0.04	0.99
	Other	25(27)	63(20)	0.347	1.48	0.67-3.33	0.813	1.26	0.19	8.24

Potential interactions between the variables in the final model were explored and a significant interaction between age and bike type was identified (see Figure 1).

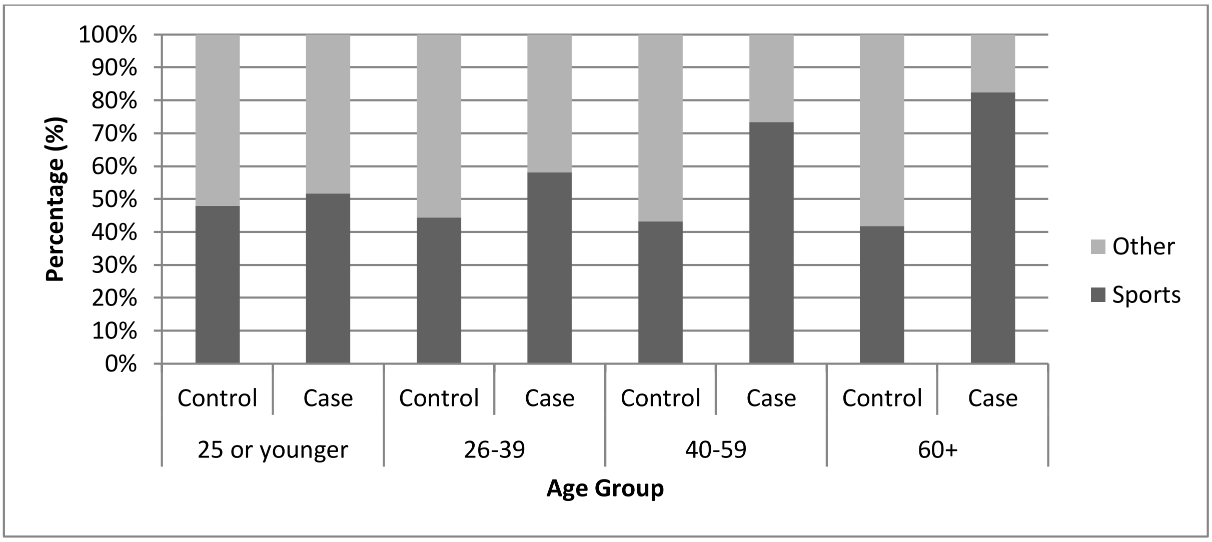

Figure 1: Variation in relationship between motorcycle type and being in crash sample by age

From the qualitative analysis, familiarity with the route was raised as a potential factor in a number of crashes. Route unfamiliarity was discussed as a factor in crashes involving cornering errors. However, route familiarity was also raised in crashes where the rider failed to stop in time. Unfamiliarity with the motorcycle being ridden was discussed as a factor in a number of crashes and manifested in inexperienced riders riding new bikes, and experienced riders moving from one motorcycle type to another.

Discussion

The findings of this study indicate that the type of motorcycle being ridden, the rider's familiarity with the motorcycle being ridden, familiarity with the crash location, the rider's use of protective equipment and age of the rider are key indicators of motorcycle crash risk. Differences in the nature of the trip between riders who crashed (cases) and those who did not (controls) might also be important. Interestingly, the elevated crash risk associated with sports bikes was more prominent among older riders.

Importantly, it may not be the type of motorcycle that increases risk, but rather characteristics of riders and/or the riding activities undertaken on the different motorcycle types. Motorcycle unfamiliarity as a risk factor is consistent with a New Zealand population based case-control analysis (Mullin et al, 2000) and observations made by Haworth et al (1997). Interestingly this also aligned with observations in the qualitative study. Route familiarity as a crash factor appears to be an uncommon finding among motorcycle crash risk literature, but is consistent with road user behaviour theories that suggest familiarity might lead to automatic behaviour, reduced attention and increased reckless behaviour (Rosenbloom et al, 2007). However, as the control recruitment method relies on the self-report of the control rider's actually riding through the crash location, and exposure to high risk roads was not controlled, this finding needs further confirmation. Unfamiliarity with the route being ridden was also identified as a contributory factor in the qualitative analysis. Together, these findings suggest a possible non-linear relationship between route familiarity and crash risk.

The protective effect observed with commuting or general transport compared to recreational purposes aligns with observations by Haworth et al (1997) who reported an increase in risk associated with non-work-related trips compared to work related trips. More recently Moskal et al (2012) also identified a protective effect for commuting riding compared to recreational riding. Coupled with our findings related to differences in the type of riding between case and control riders, this suggests further study of mechanisms (such as rider mindset/attitude) underlying these associations might be worthwhile.

Finally, the observed inverse association between the use of protective clothing – as measured by number of items worn, and being involved in a crash ought not to be construed to mean protective clothing provides any benefit in terms of crash avoidance. Rather, it it is likely that there is something intrinsically different, such as attitudes to riding and/or risk taking behaviour associated with the use of protective clothing that is also associated with a reduced likelihood of crashing. Further analysis will be undertaken to examine the nature of clothing worn by different rider-motorcycle type combinations, as well as other demographic factors. It may also be the case that this association is amplified by the crash sample representing a serious injury sample, as non-use of protective clothing has been shown to be associated with an increased likelihood of hospitalisation after a motorcycle crash due to injuries sustained (de Rome et al, 2011).

Among the limitations of this work is the fact that the control sample may not be drawn from the same population of riders included as cases. To minimise this limitation, we re-ran the model used to identify 'important rider characteristics' in the case-control analysis using data collected during a population referenced survey of motorcycle riders across NSW, and all variables remained significantly associated with the outcome of being in the crash sample. For more details on this population sample of riders see de Rome et al (2013).

Concluding comment

The findings presented here present a number of novel findings but also reinforce previous research that has found motorcycle type, for instance, is significantly associated with crash risk. These data can be used to communicate to all road users the risk and protective factors for motorcycles, and programs can be tailored to focus on these areas as a means to improving the safety of motorcyclists.

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Auto Emergency Braking (AEB) – A mass media campaign to increase fitment rates of AEB in Victoria, Australia

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Abstract

The TAC's vehicle safety campaigns began over a decade ago and focussed on encouraging consumers to purchase a safer car by consulting independent safety ratings provided at howsafeisyourcar.com.au. Recent campaigns have also focussed on specific safety features, electronic stability control (ESC) and curtain airbags, which were supported by research demonstrating their potential safety benefits.

Technological innovation proceeds rapidly within the automotive industry with manufacturers introducing a range of new safety-based technologies which have the potential to improve safety outcomes. An especially important innovation in recent times is the introduction of Auto Emergency Braking (AEB) systems. The effectiveness of AEB has been investigated in a number of studies and a range of effectiveness was found but the overall trend is a reduced number of crashes for vehicles equipped with AEB.

In 2014, the TAC ran a mass media public education campaign to raise awareness and encourage consumers to look for a vehicle with AEB when they next purchase a car. The AEB campaign was successful with regard to reach as well as message take out. The peak prompted recognition (69%) was in line with the target of (70%). Perhaps the most telling measure was the increase observed in awareness of AEB over the course of the campaign, rising to 80% of all Victorians. While there was lower than usual recall of any road safety advertising, and spontaneous recall of the campaign, this may relate to it not being perceived as a "road safety" campaign.

Introduction

Safer Vehicles is one of the four key pillars of the Safe System approach. Its power to contribute to trauma savings is captured in the following statement: If we all changed overnight from our current vehicle to the safest vehicle in our class, then the road toll would drop by about a third starting the following day! (Newstead, Delaney, Watson, & Cameron, 2004). This piece of research alone explains the continuing strong commitment of the Transport Accident Commission (TAC) towards improving the safety of vehicles on Victoria's roads.

The TAC's vehicle safety campaigns began over a decade ago and focussed on encouraging consumers to purchase a safer car by consulting independent safety ratings provided at howsafeisyourcar.com.au. Recent campaigns have also focussed on specific safety features, electronic stability control (ESC) and curtain airbags, which were supported by research demonstrating their potential safety benefits. Fitment of these two technologies has increased steadily over the years and ESC is now mandatory in all new passenger vehicles in Australia (excluding light commercial vehicles).

Technological innovation proceeds rapidly within the automotive industry with manufacturers introducing a range of new safety-based technologies which have the potential to improve safety outcomes. An especially important innovation in recent times is the introduction of Auto Emergency Braking (AEB) systems. This feature is beginning to appear in a number of models, including more affordable models, such as the Fiat Panda which retails for as little as $AUD 22,500.

What is AEB?

AEB is a generic term for vehicle safety technologies that help improve safety by identifying unsafe situations and hazards and automatically slowing the vehicle when a collision is imminent. AEB systems typically use sensors, radar, laser or cameras to monitor for risk and detect potential collisions with other vehicles, pedestrians or hazards. Although most AEB systems vary in their functionality, most systems will provide a warning (audible and/or visual) to the driver. AEB systems will also intervene and slow the vehicle down automatically if the driver does not respond. Some systems will also charge the brakes in order to provide the most efficient braking and prepare the vehicle for collision by pre-tensioning the seatbelts. If the driver takes over control of the vehicle, the AEB system disengages. AEB has the potential to prevent a crash from occurring or reduce the impact speed of a crash.

There are three different types of AEB systems:

City system – this version is designed for city driving, where crashes often occur at low speeds but can cause debilitating injury such as whiplash. Systems that can mitigate crashes at up to 20km/h are classified under this category. Typically, these systems look for the reflectivity of other vehicles and are not as sensitive to pedestrians or roadside objects.

Inter Urban – this version typically utilises long range radar to scan further ahead of the vehicle (up to 200 metres) at higher speeds between 50-80km/h.

Pedestrian – this version uses forward facing cameras to detect vulnerable road users through their shape and characteristics. The way in which pedestrians move relative to the path of the vehicle is calculated to determine whether they are in danger of being struck.

These three versions of AEB are not mutually exclusive and there are vehicles that may have two or more versions. It is important to note that within each type of system there will also be variation in functionality depending on the manufacturer and even car model (in terms of warnings, braking function, time-to-collision etc.,).

Effectiveness of AEB

The effectiveness of AEB has been investigated in a number of studies and a range of effectiveness has been found but the overall trend is a reduced number of crashes for vehicles equipped with AEB (Chauvel, Page, Fildes, & Lahausse, 2015; Insurance Institute for Highway Safety, 2011, 2012; Isaksson-Hellman & Lindman, 2012). There is limited real world performance data available for AEB at the current time, particularly in Victoria and Australia. Research by Schittenhelm (2013), indicated that 53% of all rear end collisions could be mitigated in crash severity and 35% of rear end crashes could be avoided completely. More recently Fildes et al., (2015) found similar reductions (38%) for rear-end crashes for vehicles fitted with AEB when compared to similar vehicles without AEB.

In addition, an Australian AEB simulation project estimates that AEB has the potential to reduce fatal crashes by 20-25% and injury crashes by 25-35% (Anderson, Doecke, Mackenzie, & Ponte, 2013). Research utilising insurance claims data have also found that forward collision avoidance systems, especially those that brake autonomously, showed the biggest claim reductions of 10-14% (Moore & Zuby, 2013).

Overall the research is very promising and indicates that AEB has potential to prevent crashes. Based on the research, the TAC chose AEB as the focus of a new campaign to educate the Victorian public about the technology and encourage new car buyers to consider AEB when making their purchase decision.

Communication Objectives

There were three key communication objectives for this campaign:

Increase awareness of AEB

As AEB is a fairly new technology, many car purchasers simply weren't aware of the technology, how it works and its benefits. Qualitative research confirmed that there was very little awareness of AEB. Increasing awareness was the key communication objective of this campaign.

Increasing awareness seemed to be somewhat straightforward however there was some complexity given the number of versions of AEB and the different systems available in the marketplace. Qualitative research showed that in addition to having very little awareness, consumers also confused AEB with other safety technologies such as ABS, Brake Assist and Adaptive Cruise Control.

Drive consumers to howsafeisyourcar.com.au

Another key communication objective was to drive consumers to howsafeisyourcar.com.au to find out more information about AEB, how it works, which vehicles have AEB etc. There is a lot of information about AEB and not all of it can be communicated in a 30 or 60 second television commercial (TVC). Driving consumers to howsafeisyourcar.com.au to find out more may help them to choose a vehicle with AEB.

Persuading consumers to purchase a car with AEB

Although increasing awareness of AEB was important, it may not have been enough to encourage consumers to purchase AEB in their next vehicle. Therefore it was also important to persuade consumers to purchase AEB in their next car. Persuading consumers to purchase AEB was also a key communication objective of this campaign.

Qualitative Research

The TAC engaged Luma Research to conduct exploratory qualitative research to increase our understanding of Victorian consumers' knowledge and perceptions of AEB prior to developing a brief for the advertising agency. Some key findings are as follow:

Awareness

- There was low awareness overall
- For those that were aware, they had limited knowledge of what it does and how it works
- AEB was easily confused with other technologies
- Males wanted more technical details, females asked some broad questions but assumed all cars will have the feature

Important considerations

Scenario – The research showed that it would be important to use a situation that people can relate to and to avoid situations that demonstrate 'bad behaviour'.

Target – The campaign needs to appeal to both family and non-family households.

Vehicle type – The research demonstrated that it was important to choose a vehicle that implies wide availability and affordability

Tone – The tone of the ad needed to be serious and reassuring while avoiding negative, judgemental and blaming language.

The qualitative research by Luma also found that those who had AEB were big advocates of the technology. They described situations where the technology had helped them to avoid a crash. Those that had bought a vehicle recently without AEB, were disappointed that they hadn't considered the technology after hearing the stories from those who did have the technology.

Qualitative research also identified the most acceptable generic name for the technology; auto emergency braking was the best option, rather than autonomous emergency braking.

The campaign

The TAC provided a brief to incumbent agency Clemenger BBDO Melbourne. Clemenger developed 4 creative concepts which were tested with qualitative research and the strongest concept was chosen for development.

It was recognised that it would be important to include all three versions of AEB in the broader campaign; however, it would be difficult to demonstrate all three versions in a 30 or 60 second TVC. Inter urban AEB was chosen for the TVC as analysis of TAC claims data showed that rear end collisions in speed zones from 60 km/h to 80 km/h account for the highest number of claims and the highest costs. Additionally, the low speed AEB systems are more common and appear to be making their way into the market naturally. Inter urban systems are lagging behind and could do with a push to increase uptake and availability.

The final TVC shows a man driving through traffic when another car suddenly cuts in front of him at the lights. A voiceover describes AEB as his car stops safely. Another version of the man's car continues on and crashes into the back of the other car, giving him a bloody nose, showing what happens without AEB. The tagline of the campaign was "AEB senses danger then brakes". The campaign was run across all regular media channels, including TV, outdoor, radio, print, online and through TAC partnerships.

The campaign had the following objectives:

- 70% campaign awareness among the Victorian community
- An increase in overall awareness rate of the “How Safe is Your Car” (HSIYC) website to 60%.
- Contribute to an increase in the proportion of people considering safety as a high priority when purchasing a vehicle.
- Set a benchmark for AEB awareness as tracked by the TAC’s Public Education Evaluation Program (PEEP)
- Contribute to the demand of AEB by purchasers and long term, aim to make AEB a standard safety technology in the Victorian passenger car fleet.

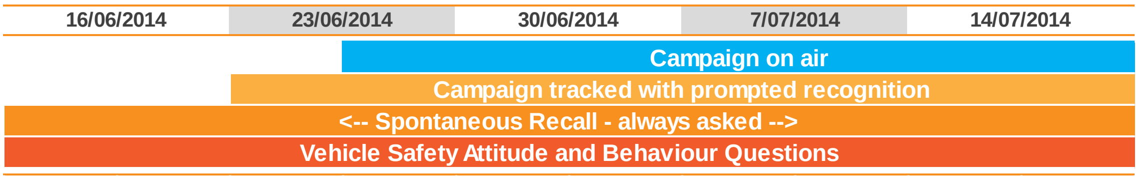
Methods

PEEP is conducted by Wallis Consulting Group on behalf of the TAC. PEEP is a continuous tracking program surveying 100 Victorians each week with specific campaign measures and road safety attitudes and behaviour questions. PEEP was used to evaluate the AEB campaign.

Timeframe

The AEB campaign ran from June 26 to July 20 and was measured in PEEP from June 23 to July 20. Questions relating to attitudes and behaviours were asked from the week commencing June 16 to the week commencing July 14. The time period is shown in the Figure below:

Figure.1 Time period for AEB campaign tracking



The monitor tracked a number of aspects of the campaign, including:

- Spontaneous recall of the advertising;
- Prompted recognition (including recall of HSIYC website); and,
- Attitudes and behaviour relating to vehicle safety.

Recruitment

TAC campaigns are “on air” at all times and so recruitment is ongoing most of the year. All Victorians over the age of 18 are in scope for the survey, although non-drivers complete a shorter version of the questionnaire. Multiple sampling methods are used to obtain participants including VicRoads registration and licencing database, randomly selected fixed line telephone numbers (RDD) and an online panel. All respondents have the option to complete the survey online and the VicRoads and RDD sample may complete online or via Computer Assisted Telephone Interview (CATI). The VicRoads sample is sent a letter from the TAC/Wallis inviting them to participate either online or to wait for a telephone call. Quotas are applied for age, sex and location for the online panel and combined VicRoads/RDD sample. The data are weighted to ABS 2011 Census data for age, gender and location. Weights are re-calculated each week.

Questionnaire

The PEEP questionnaire includes questions on the following:

- Demographics (including age, sex, location, license type, vehicle type, kilometres etc.,)
- Spontaneous recall of road safety advertising
- Prompted recall of current campaign/s
- Driving/Riding attitudes and behaviours
- Media consumption

Results

Spontaneous Recall

Spontaneous recall of road safety advertising in general is measured continuously every week. Just over a third (37%) of all respondents (n=401) recalled seeing any road safety advertising in the period AEB was on air. When asked to describe the ad they had seen, 6% of all respondents mentioned an ad that related to "Vehicle Safety", with 5% of all respondents specifically mentioning the "AEB" campaign. Spontaneous recall of "Vehicle safety" advertising was very low in the first two weeks of the campaign (2% and 1% respectively). Recall peaked in the third (11%) and fourth (12%) weeks before trailing off (7% and 4% in the two weeks following the campaign).
Those who recalled seeing an ad relating to "Vehicle Safety" were largely on target (78%) with the message they believed the ad was trying to convey. The key messages were:

- When buying a new car find out about emergency braking (49%);
- Buying a safer vehicle / vehicle safety (24%); and,
- Slow down / drive more slowly (10%).

Prompted recognition

After hearing a description of the AEB ad on the telephone, or reading a description of it online, just over six in ten (62%) respondents recognised the AEB ad over the three weeks it was on air, with recognition peaking in the final two weeks of the campaign (69%). The peak result meets the campaign objective of 70% recognition. Recognition was similar across most demographics, although drilling down into the data shows recall was highest amongst males aged 40 to 59 years (77%). Those who were intending to purchase a car were as likely to see the ad as those who were not. Given that recognition was high amongst all Victorians, the message was pervasive rather than targeted.

Prompted message take out

Respondents who saw the ad were asked what they thought the ad was telling people to do. Compared to the message take out amongst those who recalled the ad spontaneously, on target message take out was lower, at 65%. The key messages were:

- When buying a new car find out about emergency braking (40%);
- Buying a safer vehicle / vehicle safety (20%);
- Slow down / drive more slowly (10%);
- Concentrate while driving / keep your eyes on the road (9%); and,
- Drive safely / carefully / responsibly (9%).

Overall, 65% of Victorians believed the campaign was relevant to them. The proportion who felt it was relevant increased over the course of the campaign, with 52% believing it was relevant in the first week rising to 74% in the final week. The results suggest that the campaign was felt to be more relevant amongst those who were considering buying a vehicle in the near future.

There is a large difference between spontaneous recall and prompted recognition levels. Based on qualitative development work we suggest this may be due to the fact that "Vehicle Safety" campaigns are not perceived to be in the "road safety" category by respondents.

Awareness of the HSIYC website

Awareness of the website increased from 47% in the first week of tracking (prior to the campaign being launched) and increased to 55% in the final two weeks of the campaign. We note that the target was 60%.

Advertising effectiveness and efficiency

Wallis uses two measures to judge the effectiveness and efficiency of the campaign. The effectiveness is determined by effective recognition, which is the proportion who recognised the campaign and took an "on-target" message from it. The AEB campaign had an effective recognition of 40%. Both the reach and message take out measured well, while neither was outstanding.

Vehicle safety measures

While vehicle safety is not a road safety issue that Victorians say they have discussed with friends and family, and not one they think of as being a key issue facing Victoria, it is nonetheless important. The majority (90%) believe it is worth spending extra to buy a safer car, and half (51%) feel strongly that this is the case. This sentiment is fairly consistent, with only a minor difference in that females (93%) are slightly more inclined than males (87%) to be willing to spend more for safety features. Although most feel it is worth spending more, not all are able to. Just shy of seven in ten (68%) agree that they can afford these features. Younger drivers were the least likely to be able to afford these features (53%) and those aged between 60 and 69 years (85%) the most able to afford them. Additionally, those planning on purchasing in the next 24 months (37%) were more likely to *strongly* agree than those who were unsure or not planning a purchase (26%).

Overall the majority (67%) of Victorians were aware of AEB. However, the campaign clearly had some influence, with awareness climbing from 57% prior to the campaign to 80% at the end. Furthermore, 84% of those who had seen the ad were aware of AEB versus 45% of those who had not. Although the majority is aware of the technology, only 5% believe they have it in the vehicle they mainly drive. Two thirds (67%) believe it is likely that the next car they purchase will have AEB. Those planning an imminent purchase (next 12 months) were slightly less likely to think their new car will have AEB versus those who are planning to purchase at a later date (65% versus 75%).

Conclusion

The AEB campaign was successful with regard to reach as well as message take out. The peak prompted recognition (69%) was in line with the target of (70%). Perhaps the most telling measure was the increase observed in awareness of AEB over the course of the campaign, rising to 80% of all Victorians. While there was lower than usual recall of any road safety advertising, and spontaneous recall of the campaign, this may relate to it not being perceived as a “road safety” campaign.

The TAC will continue to run this campaign at key times and monitor community perceptions and fitment rates of AEB.

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Predicting occupant risk indicators for frontal impacts with redirective crash cushions

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Abstract

Crash cushions are devices deployed on the road network in order to shield fixed roadside hazards and the non-crashworthy ends of road safety barriers. However crash cushions vary in terms of configuration and operation, meaning that different devices may also vary in terms of ability to mitigate occupant risk. In this study, data derived from crash testing of eleven redirective crash cushions is used as the base input to a numerical procedure for calculation of occupant risk indicators Occupant Impact Velocity (OIV), Occupant Ridedown Acceleration (ORA) and longitudinal Acceleration Severity Index (ASI) for a range of simulated impacting vehicles (mass 800 kg to 2,500 kg) impacting each crash cushion at a range of impact speeds (18 m/s to 32 m/s). The results may be interpreted as demonstrating firstly that enhanced knowledge of the performance of a device over a range of impact conditions, i.e., beyond the crash testing, may assist in determining the crash cushion most suited to a particular application; secondly that a more appropriate conformance test for occupant risk would be a frontal impact by a small (light) vehicle travelling parallel to and aligned with the centreline of the crash cushion; and thirdly that current documented numerical procedures for calculating occupant risk indicators may require review.

Introduction

Crash cushions fall within the definition of an attenuator provided by Australian/New Zealand Standard AS/NZS 3845:1999 *Road Safety Barrier System*s, which is a "*device that prevents an errant vehicle from impacting hazardous objects by gradually decelerating the vehicle to a safe stop*" (Standards Australia, 1999, p. 9). While crash testing provides an objective basis for product evaluation against a standard, different crash cushions are observed to vary in terms of geometry and operation (Ko, Jang, Joo, Kim, & Kim, 2014; Schrum et al., 2015). Hence it is reasonable to suppose that different crash cushions may also vary in terms of ability to mitigate occupant risk. The Manual for Assessing Safety Hardware (MASH) (AASHTO, 2009), which is the preferred test protocol for use in the United States, specifically recognises that some crash cushions may be 'staged' (meaning that the device may "*be tuned to meet the testing requirements… without adequately accommodating mid-sized vehicles*" (AASHTO, 2009)), while European Normative EN1317-3:2010 (European Committee for Standardization, 2010) makes express provision to categorise crash cushions in terms of the magnitude of occupant risk indicators measured during crash testing. However the extent to which different devices, whether staged or not, may influence severity outcomes for vehicle occupants is not well explored.

Schrum *et al* report on an economic evaluation of a range of in-service crash cushions in a range of roadside configurations with the qualification that "*…accident costs were not influenced by the crash cushion's ability to reduce severity because RSAP is not capable of treating crash cushions differently*" (Schrum, Albuquerque, Lechtenberg, & Reid, 2012, p. 30). Likewise, Elvik's meta-analysis (Elvik, 1995) of evidence from evaluation studies of the safety value of guardrails and crash cushions identifies a crash cushion as a generic countermeasure: it does not distinguish between competing devices. Variations in performance do exist between different crash cushions though, as is evidenced by Ko et al in a South Korean study of devices crash tested to the European test protocol (Ko, et al., 2014). In terms of device selection, La Torre et al state "*Guidance on the need to install crash cushions is very limited*" (La Torre et al., 2014, p. 4), while Sicking and Ayton specifically highlight the development of "*clearly defined classifications for crash cushions*..." as a preferred strategic research objective for the Transportation Research Board's Roadside Safety Design Committee (Sicking & Ayton, 2012, p. 38).

The point here is that road authorities are required to make decisions about road safety hardware, which necessitate consideration of the consequences of those decisions. However, knowledge of the possible differential safety performance of crash cushions that have been tested to meet the requirements of AS/NZS 3845:1999 is not well studied or documented.

Objective

The objective of this study is to develop an understanding of the extent to which occupant risk indicators measured and reported during end-on conformance crash testing of crash cushions might be expected to vary as a function of the device itself and variation in the impact configuration in terms of vehicle mass and vehicle speed.

Methodology

Consistent with the provisions of Australian/New Zealand Standard AS/NZS 3845:1999, National Cooperative Highway Research Program (NCHRP) Report 350 establishes the test criteria for conformance testing of road safety hardware, including the conformance tests used to evaluate the performance of crash cushions. With reference to section 3.2.2.2 of NCHRP Report 350, the single test pertinent to this study is test no. 31, which is "*intended to evaluate the capacity of the device to absorb the kinetic energy of (a 2,000 kg utility) vehicle (structural adequacy criteria) in a safe manner (occupant risk criteria)*" (Ross, Sicking, Zimmer, & Michie, 1993, pp. 17-18). The configuration for this test is depicted in Figure 1.

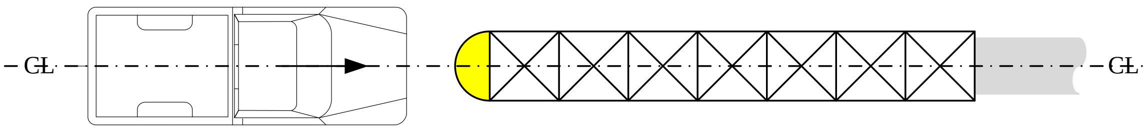

Figure 1. Diagram for test no. 31

Variation in device performance for this impact configuration is depicted diagrammatically in Figure 2, which shows Kinetic Energy Dissipated plotted against Deformation Length for impacts with three different attenuating devices (A, B and C). Since Energy = Force x Distance, the slope of the line at any point (i.e., Δ Energy ÷ Δ Distance) represents the instantaneous Force required to displace the system (i.e., resistance to deformation, or 'stiffness'). Further, since acceleration is directionally proportional to Force for a given mass, the slope of the line is also representative of acceleration: a steeper line represents a sharper (or more severe) acceleration, while a flatter (i.e., tending towards horizontal) line represents a more forgiving acceleration.

With reference to Figure 2, the three devices (A, B and C) appear to mitigate roughly the same amount of kinetic energy, albeit over different deformation lengths. The distance required to arrest the vehicle impacting device B is the greatest, and hence the average deceleration experienced by the vehicle (and its occupants) will be lowest. Conversely, device C arrests a vehicle in the shortest distance, and so the average deceleration experienced by the vehicle (and its occupants) will be greatest. On this basis alone it might be presumed that device C is stiffer than device B while device A is somewhere in between.

However, more critical analysis of each trace shows that device A absorbs a significant proportion of the impacting kinetic energy over a short distance close to the start of the system, suggesting that this is where the device is stiffest. Meanwhile device C appears to be staged such that the back end of the system is stiffer than the front end of the system. Finally the trace for device B represents regular stiffness throughout most of the length of the device. Arguably device B presents a less severe impact than device A for a range of vehicles, since it is shown to be generally less stiff throughout its length, but it requires a longer installation to do so. Device C is shown to be similar in stiffness to device B until roughly half the initial kinetic energy is absorbed at which point the device becomes somewhat stiffer, and therefore possesses capacity to accommodate the same impact in a shorter length than device B. In terms of occupant risk, a concern is that a small or mid-sized vehicle may compress the weaker front end of the system before encountering a stiffer part of the system, which for a small or mid-sized vehicle may result in higher decelerations and increased risk of occupant injury than are experienced by occupants of larger vehicles.

Thus, while these three devices are in one sense equal since they each satisfy the same crash test protocol, it is arguable that occupant severity outcomes may vary, both as a function of the device itself and also as a function of the impacting vehicle.

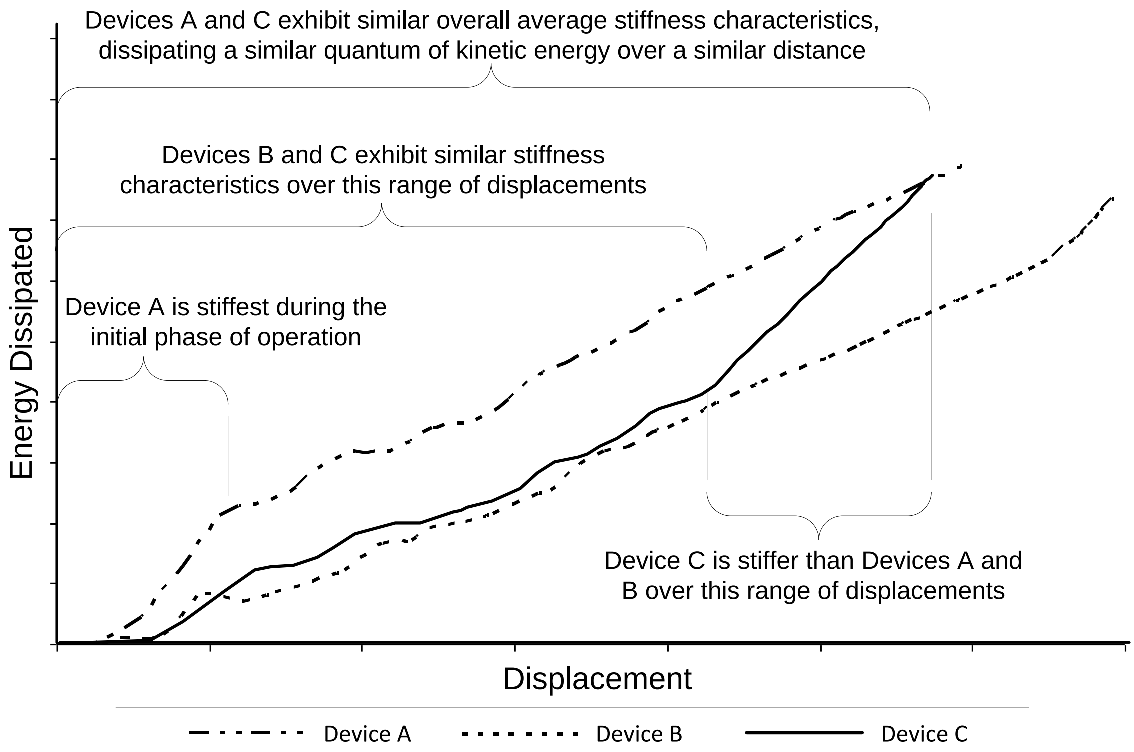

Figure 2. Diagrammatic representation of Kinetic Energy Dissipated plotted against Deformation Length for similar magnitude impacts with three different attenuating devices

Appendix G of the Manual for Assessing Safety Hardware (MASH) documents a numerical procedure to transform crash cushion crash test data obtained during testing with a 2,270 kg to data for a simulated 1,500 kg vehicle impact (AASHTO, 2009, pp. 229-233). The procedure assumes that the acceleration trace recorded by the accelerometer at the centre of mass of the impacting vehicle during a crash test can be integrated to generate the force-deflection characteristics of the article being tested, and that these characteristics can then be applied to a theoretical 1,500 kg impact in order to produce a theoretical deceleration trace for a simulated 1,500 kg vehicle impact.

This study extrapolates from the MASH methodology as follows. Whereas the capacity test impact according to the MASH test protocol is undertaken with a nominal mass 2,270 kg vehicle, this study uses as a baseline for analysis crash tests that are conducted in accordance with NCHRP

Report 350, which specifies a nominal 2,000 kg test vehicle. Only crash cushions with test results for a 2,000 kg nominal mass vehicle impacting at nominal speed 100 km/h (or greater) and which nominally meet the requirements of AS/NZS3845:1999 are considered for analysis, which results in eleven (11) different devices being included in the dataset, with the data not associated with the identity of the device.

The procedure (modified to account for typographical errors in the MASH document) is then applied to simulate impacts by a range of vehicles with mass varying from 800 kg to 2,500 kg, and with impact speeds varying from 18 m/s to 32 m/s (~65 km/h to ~115 km/h). The resultant acceleration-time data are then used to calculate occupant risk indicators Occupant Impact Velocity (OIV), Occupant Ridedown Acceleration (ORA) and longitudinal Acceleration Severity Index (ASI) for each impact condition combination of mass and speed for each crash cushion studied.

Both OIV and ORA are occupant risk indicators based on the simplified point mass, flail-space model for assessing risk to occupants due to vehicular accelerations originally presented by Michie (Michie, 1981). OIV provides an estimate of a body when it reaches the extremities of a flail space and simulates the velocity the head would impact the interior of the vehicle. The ORA provides of a measure of the acceleration of an occupant's head after it has reached the extremities of the flail-space. ASI uses "*acceleration time-histories measured at the centre of mass of the impacting vehicle*" to provide "*an indication of the deceleration over a 50ms period compared to tolerance limits for occupants wearing a lap belt only*" (Sturt & Fell, 2009, p. 165), and is evaluated over the whole impact. Since reporting of OIV and ORA are mandated in both NCHRP Report 350 and MASH, and ASI is both encouraged in those two test protocols and is a requirement of European Normative EN1317-3:2010, they together are regarded as appropriate metrics for this comparative study. Whilst ASI is a function of accelerations in all three axes "*lateral and vertical accelerations have virtually no effect on the results of the occupant risk values in head-on crashes with attenuator systems*" (AASHTO, 2009, p. 230), and so longitudinal ASI is calculated here using only the longitudinal acceleration data.

Limitations

This study is constrained by limitations, which are described here.

- Raw data files for acceleration traces were not available. As such, the data used as a baseline from which the consequent calculation is undertaken is derived by digitization of hard copy acceleration traces obtained from crash test reports, and which are of varying quality. Methods employed to attempt to verify the validity of the digitized traces has included:

    i. A comparative visual check by overlay of the calculated velocity-time and velocity-displacement traces (where provided in the available test data) was undertaken. Typically, this has produced a reasonable match.

    ii. A quantitative comparison between the calculated stopping distance and the aggregate displacement of the test article and any damage to the test vehicle was undertaken wherever such information was available in the test report data. Whilst vehicle distortion was found to be not well reported, this resulted in variances ranging from 4% under-prediction to 14% over-prediction of stopping distance.

    iii. A quantitative comparison of occupant risk indicators was undertaken. Calculated values for OIV were found to be closely aligned with reported values with differences ranging from -3.3% under-prediction to +4.7% over-prediction. ORA and ASI were less well matched with respective discrepancy ranges of -8% to +30% and -17% to +12%. While the variation in ORA and ASI is likely to be related to the quality of the source acceleration trace, it is notable that Post impact Head Deceleration (PHD) (which is the EN1317 'equivalent' of ORA) "*has been deleted from EN 1317 because (it) was considered to be not a reliable measure. The concept is correct, but the measurement is too sensitive to oscillations in the acceleration trace*" (Anghileri, 2013).

- The procedure for transforming crash test data to occupant risk indicators is based on the results from an accelerometer situated at the centre of mass of the test vehicle, with the assumption that the displacement calculated from that data matches the displacement of the device being tested. However the recorded force-deflection characteristics also include vehicle crush: the base case for each device includes the combined crush characteristics of the tested device and the impacting vehicle.

- Similarly, the procedure assumes uniform material performance under different loading rates. However crushable materials may be expected to demonstrate non-linear performance.

- The authors have been unable to use crash test data to calibrate the model. Calibration of the model would require similar testing of an identical device with a vehicle of a different mass and/or speed. Typically, available full-scale test results conducted on an identically configured device with an alternative impact mass are from tests conducted in accordance with NCHRP Report 350 test no. 30, which is a quarter-offset test. The eccentricity of test no. 30 invariably introduces rotational motion into the impacting vehicle, which does not suit this method of simulation.

- Combinations of impact speed and vehicle mass that exceed the capacity of the studied devices are used in the study, and the results of these simulations are included in the reported results. In these cases the simulated impact is not concluded (i.e., the vehicle is not brought to rest). The results do not reflect the increased occupant risk indicators that would likely result from exhausting the capacity of the system for these impacts.

These limitations taken together mean that the absolute values of the results must be treated with caution. However the trends from the analysis remain useful.

Results

Figure 3 panels (a-c) contain scatter-plots for respectively OIV, ORA and ASI each categorised by a simulated vehicle mass (800 kg to 2,500 kg) impacting at 28 m/s (nominally 100 km/h) for the eleven devices considered in this study. For comparison, panels (d-i) contain scatter-plots for the same occupant risk indicators for simulated vehicle impacts of mass 1,100 kg and 2,000 kg categorized by impact speeds (18 m/s to 32 m/s)(~65 km/h to ~115 km/h) for the same eleven devices.

While absolute values are not the focus here, it is useful to observe these results in the context of the threshold values prescribed by the respective test protocol for the three occupant risk indicators. These are provided in Table 1 and are included for reference as horizontal lines in Figure 3.

Table 1. Test protocol threshold values

Occupant risk indicator	Preferred limit	Maximum	Test Protocol
OIV (m/s)	9	12	NCHRP Report 350
ORA (g)	15	20	NCHRP Report 350
ASI	1.0	1.4	EN1317-3:2010

The results presented in each of the panels in Figure 3 indicate a dispersion of occupant risk indicator values for each impact condition. Closer analysis of the results (not presented here) suggests that this dispersion is a function of the device itself: i.e., devices that have satisfied the requirements of the same test protocol may return different occupant severity outcomes when subjected to the same impact configuration. Further panels (a-c) indicate that the mass of the impacting vehicle has a pronounced effect on estimated occupant severity values, while variation in speed has less effect (panels (d-i)), especially for the heavier vehicle.

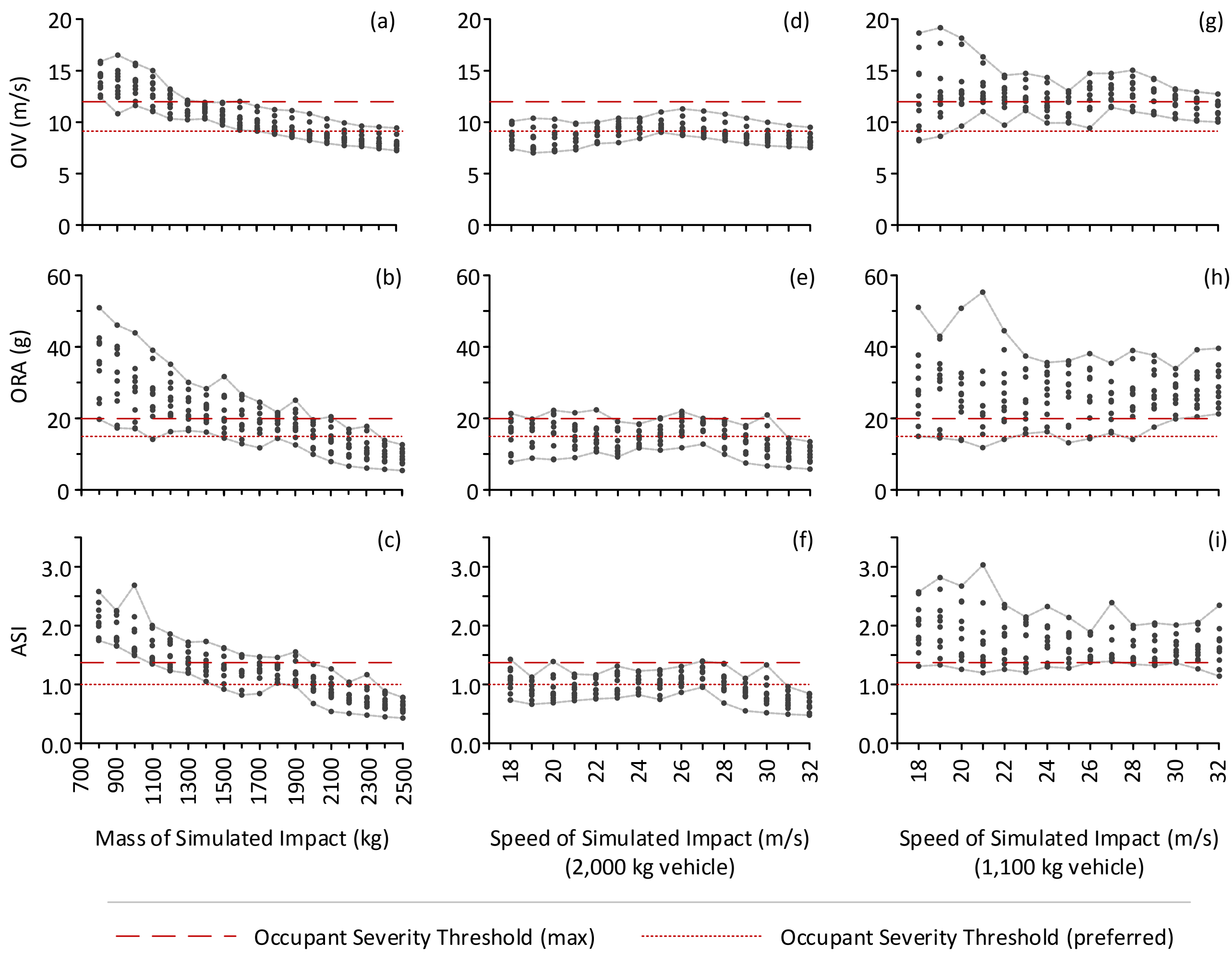

Figure 3. OIV, ORA and ASI for all studied crash cushions (n=11) categorized (in panels a-c) by vehicle mass (800 kg to 2,500 kg) impacting at 28 m/s and by impact speed (18 m/s to 32 m/s) for vehicles of mass 2,000 kg (panels d-f) and 1,100 kg (panels g-i)

With regard to variation in mass (panels (a-c)), while there is some scatter in the data, it is evident that there is a trend towards decreasing occupant severity value with increasing impacting vehicle mass for all three occupant risk indicators. This must be expected, since, for the same resistance heavier vehicles will decelerate less rapidly. Also apparent is that the range of results for each mass category generally diminishes with increasing mass, suggesting that occupant severity is more likely to be sensitive to variations in crash cushion performance at lower mass impacts than at higher mass impacts.

By comparison, panels (d-i) indicate that the results are not as sensitive to variation in impact speed as they are to impact mass. Each of the plots show that the magnitude of occupant severity values remains broadly constant across the range of impact speeds (18 m/s to 32 m/s). However panels d-f show that the variation in results for all three occupant risk indicators remain in fairly narrow bands for the 2t vehicle while panels g-i show that the variation in results become increasingly spread for the 1,100 kg vehicle. This reiterates the observations above that the range of results for each mass category generally diminishes with increasing mass.

Discussion

The results from this study indicate that occupant risk does vary as a function of the crash cushion being impacted, i.e., devices that satisfy the same test protocol may not mitigate risk equally. Further, the results from this study indicate that occupants of lighter vehicles may have an elevated exposure to risk of injury than do occupants of heavier vehicles in end-on impacts with crash cushions that have satisfied the requirements of crash testing. This should be no surprise: elementary physics would suggest that for the same initial impact speed a lighter vehicle will deform a device a lesser amount than will a heavier vehicle, and as such will decelerate at a faster rate. Moreover the results also indicate that the outcome for a vehicle occupant is likely to vary more widely as a function of both the crash cushion itself and the speed of impact for lighter mass impacts than for heavier mass impacts.

European Normative EN1317-3:2010 makes a distinction between higher performing crash cushions and lower performing crash cushions, using ASI as a classification indicator. Currently, U.S. and hence Australian/New Zealand test requirements make no such provision for classification of crash cushions. The results of this study, whilst coarse, could be argued to support the notion of ranking crash cushions by occupant severity performance in end-on impacts for a range of vehicle impact configurations.

However, in terms of absolute values, MASH considers that the results simulated for lighter vehicles would be conservative due to variations in vehicle stiffness (AASHTO, 2009, pp. 229, 232-233): that is to say that MASH expects that simulated occupant severity results would be higher than would be experienced in actual impacts. This is confirmed by Ko et al who find that "*the MASH procedure overestimates the risk values significantly in most… cases*" when attempting to predict the occupant risk indicators for a 900 kg vehicle impact from the crash test data for a 1,300 kg vehicle impact (Ko, et al., 2014, p. 167). It is reiterated that the absolute values of occupant severity calculated here must be treated with caution. Notably, Ko et al (2014) present a validated procedure for estimating the crash data for any mass vehicle. However, while the procedure appears to be suitable for calculating occupant severity indicators OIV and ORA, the procedure does not appear to be suitable for recalculating a simulated ASI.

Gabauer and Gabler in any case question the absolute value of the occupant severity criteria OIV and ORA concluding among other things that "*current roadside occupant risk criteria are not an accurate measure of occupant risk for individual vehicles*" (Gabauer & Gabler, 2008, p. 147). As such, the consequences of exceeding the nominated thresholds for either OIV or ORA are undetermined. Roque and Cardoso report on efforts to correlate ASI with actual injury risk (Roque & Cardoso, 2013, p. 25), indicating that an ASI of between 1.9 and 2.3 might correspond with a 36 millisecond Head Injury Criterion (HIC_{36}) value of 1,000, which is regarded as a threshold for unacceptable likelihood of serious head injury.

Notably, the results from this study include ASI values exceeding 1.9-2.3 for some crash cushions in simulated impacts by vehicles of mass 800 kg to 1,100 kg at 100 km/h. Useful further work in this regard would be to establish through in-service performance evaluation whether (and the extent to which) injury outcomes consistent with a 36 millisecond Head Injury Criterion (HIC_{36}) value of 1,000 are occurring as a result of lighter vehicle impacts into crash cushions.

Dreznes and Denman advocate that a test protocol should test for a range of vehicle masses, arguing that "*occupants of different weight passenger cars will not react the same during an impact with a crash cushion*", and that a "*range which represents 90% of the passenger cars on the road is* *achievable and is recommended*" (Dreznes & Denman, 1991, p. 56). MASH does include a large vehicle test using a 2,270 kg pick-up (test no. 31) and a small vehicle test using an 1,100 kg sedan (test no. 30). However, test no. 30 is an offset impact, with the device loaded eccentrically and which typically yaws the vehicle during impact with the nose of the device. This means that the crash cushion does not fully arrest the vehicle and that the vehicle loses contact with the crash cushion with some residual kinetic energy. Notwithstanding the limitations of this study, the results suggest that a more appropriate test for the occupant risk indicators considered in this study would be a test with the smaller test vehicle (1,100 kg) in the configuration depicted in Figure 1, i.e., an end-on impact by a vehicle travelling parallel to and aligned with the centreline of the crash cushion. It is noted that the European Normative EN1317-3:2010 specifies tests in this configuration for a range of impacting masses.

The MASH test protocol makes provision for an intermediate vehicle test using a vehicle of mass 1,500 kg if there is evidence that a device is staged. Notably commentary paragraph A4.2.1.1 of MASH states that the 1,500 kg vehicle ("*a mid-size sedan*") is selected because "*in analyses of impacts with vehicles ranging from …1100 to 2200 kg… the highest ridedown accelerations were found to occur when the impacting vehicle mass was between… 1300 to 1700 kg*". *The mid-sized vehicle mass was set to 1500 kg because it fell within the critical range and it provided some consistency with European safety hardware procedures*" (AASHTO, 2009, p. 138). The results of this study suggest though that occupant risk continues to escalate for occupants of vehicles that are lighter than 1,500 kg generally for all devices rather than specifically for devices that are staged.

It is suggested that practitioners required to select a device should have knowledge of how a device performs across the range of expected impacts, regardless of whether the device is staged or not. As such, the application of the results from this study in terms of actual occupant injury occurring as a result of in-service impacts into crash cushions as a function of vehicle mass is a subject that deserves further exploration.

Conclusion

Acceleration traces from end-on impact crash tests with eleven redirective crash cushions have been analysed and used to estimate occupant severity indicator values for a range of vehicular impact masses and impact speeds. Devices that have satisfied a given test protocol to the same test standard are shown to present some likelihood of differential performance. The results indicate that, in terms of occupant severity, variation in crash cushion performance during end-on impacts increases with decreasing impact mass, and to a lesser extent decreasing impact speed. The results also indicate that impact severity increases with decreasing mass of the impacting vehicle. In broad summary the results from this study indicate that different devices may perform differently for the end-on impact configuration.

The results of this study may be argued to support the notion of ranking crash cushions in terms of occupant severity performance for a range of impact conditions. It is not suggested here that the results of this paper are in any way definitive: in the first instance the impact condition (end-on, zero offset) is one impact configuration among a continuum of possible impacts. However, the results do indicate that some devices are more forgiving than others for the end-on impact configuration. As such, enhanced knowledge of the performance of a device over a range of impact conditions, i.e., beyond the impact conditions prescribed in crash test protocols, may assist in determining the device most appropriately suited to a particular application.

In this regard, the results may also be interpreted to suggest that a more appropriate test for occupant risk would be a frontal impact test with a small (light) vehicle in the configuration depicted in Figure 1, i.e., an end-on impact by a vehicle travelling parallel to and aligned with the centreline of the crash cushion.

Finally, consistent with the findings of Ko et al (2014, p. 169), is that the results may be interpreted as indicating that the current procedure documented in the Manual for Assessing Safety Hardware (MASH) for estimating occupant risk indicators for an intermediate (1,500 kg) vehicle may require review.

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Effectiveness of portable speed warning signs

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Abstract

Speeding is a continual issue for road authorities to manage, especially on local streets and around schools. Speeding increases the required stopping distance of vehicles to avoid an accident. This in turn, results in increased occurrences of accidents and their associated severity. Speeding may be due to poor driver behaviours such as hooning, distracted drivers, or technical issues such as vehicle defects or not knowing basic road rules, for example, 50km/hr on local roads in South East Queensland.

Brisbane City Council is taking a proactive approach by installing 26 portable speed warning signs on streets and roads to reduce speeding and help increase safety. The portable speed warning signs have been operational since November 2013 and in the 17 months up to the end of the March 2015, have subsequently captured 25.1Million motorists and advised them to slow down if driving over the posted speed limit.

During the 17 months, the 26 signs have been moved around Brisbane 175 times. The data from each of these sites has shown a marked decrease in the number of motorists travelling over the speed limit as a consequence of being advised of their travelling speed.

Background to portable speed warning signs program

The Portable Speed Warning Signs Program is part of Lord Mayor Graham Quirk’s commitment to making Brisbane’s suburban streets safer. The program aims to increase motorists' awareness of their travelling speed and to achieve better adherence to the speed limit in locations with identified or suspected speed issues. To date the program has shown a marked decrease in the travelling speed for motorists travelling over the speed limit with average speed reduction of 9.5km/hr after passing the signs.

The main phases of the project detailed within this report are as follows:

- Site Assessment and Resident Consultation
- Sign Installation
- How the Signs Function
- Analysis of Results

Site Assessment and Resident Consultation

Each of the 26 local wards within Brisbane City Council has a list of requested streets for the portable speed warning signs. These streets are largely based on requests from resident's and council officers' recommendations from traffic investigations. From each local councillor's ranked order of their sites, a desktop site assessment is undertaken to see if a proposed location/s can be found. This is because the signs are not suitable for all locations within the road network due to two main requirements:

1. longitudinal placement along the streets so that the sign can detect approaching vehicles,
2. sufficient sunlight as the signs are solar powered.

The factors for the longitudinal placement include:

- sufficient forward visibility free from presence of obstructions such as trees, other road signs, and conflicts and decision points to ensure drivers have sufficient time to read the messages posted. This is generally 3 seconds on local streets with a minimum of 50m.
- sufficient separation after the portable speed warning sign to other road signs, conflict and decision points. This is generally 2 seconds on local streets with a minimum of 30m.
- constant longitudinal grade and limited vertical curvature on approach to the sign. This is generally 3 seconds on local streets with a minimum of 50m.

From the proposed location/s, a site visit is undertaken to complete a detailed site assessment to determine if an appropriate location can be found in the ***physical*** environment by assessing the following;

- ensuring the solar panels receive adequate sunlight
- ensuring separation between other traffic signs to ensure drivers have sufficient time to read the messages posted,
- visual impact on adjacent residents,
- clearance from conflicts such as driveways and power poles,
- clearance from low hanging power lines and television cables, and
- clearance to underground services by dial-before-you-dig enquiry.

Once a ***physical*** location has been confirmed, the directly affected property owner/s are engaged via letter to seek their comments on the installation of the portable speed warning sign on the road verge in front of their property.

Portable Speed Warning Sign Installation

Installation of the portable speed warning signs involves the construction of a small concrete foundation below the ground on Council owned footpath/verge or sometimes median as shown in Figure 3.1.

Figure 3.1 – Portable Speed Warning Sign Footing Installed on Council Footpath/Verge

Once the concrete has cured, the sign is installed on a slip based pole and the solar panel connected as shown in Figure 3.2. The electrical technicians configure the sign to the speed environment which includes if it is within a school zone or non-school zone.

Figure 3.2 – Portable Speed Warning Sign Installed on Council Footpath/Verge

Once the speed sign is removed, the lid will remain and sits flush with ground level as shown in Figure 3.3. This means that the site can be used again if speeding at this location becomes an issue.

Figure 3.3 – Portable Speed Warning Sign Removed

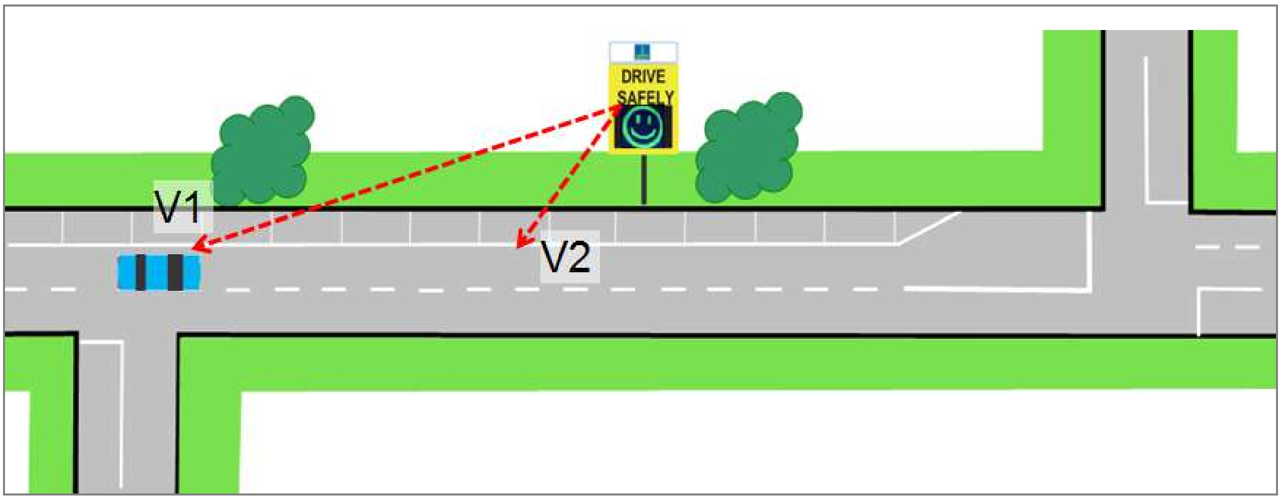
How the Portable Speed Warning Signs Function

The portable speed warning signs measure the speed of each motorist then displays a message dependent on their speed. The signs also record the initial entering speed and the final or exiting speed of each motorist.

The following naming convention for the speed records used within this report is as follows:

- V1 – initial speed of the vehicle entering the radar range of the sign
- V2 – final speed of the vehicle exiting the radar range of the sign

Figure 4.1 – How the Portable Speed Signs Function



The default setting for the sign is blank and as a motorist approaches the sign, the vehicle's speed is detected by the sign's radar and one of the following three messages displayed:

1. If the motorist is driving at or below the speed limit, a smiley face message is displayed as shown in Figure 4.2,
2. If the motorist is driving above the speed limit by up to 9km/h, the vehicle's speed is displayed below a 'YOUR SPEED' message as shown in Figure 4.3,
3. If the motorist is driving 10km/h or more above the speed limit, the sign is programmed to display a 'SLOW DOWN' message as shown in Figure 4.4.

Figure 4.2 – Message 1

Figure 4.3 – Message 2

Figure 4.4 – Message 3

Additionally, the message changes as the vehicle's speed changes whilst within the radar range of the sign.

There are several key aspects in relation to the messaging and operation of the portable speed warning signs in Council's program:

- the third message doesn't display excessive speeds so motorists don't try and display a high speed reading,
- the signs remain at each location for at least one month before being moved to a new location. This is to allow the speed warning signs to have a positive effect on motorists driving behaviour,
- the speed readings are not used for the issuing of any infringement notices as the purpose of the speed radar is only to enable feedback to motorists of driver speed. The signs also don't have a camera to photograph vehicles. If a site shows excessive and continual speeding, then we do however recommend to the local councillor that Queensland Police Services (QPS) assesses the location to their criteria and undertakes enforcement if considered appropriate.

Analysis of Result

As part of the successful tender's product, analysis software was also supplied. It provides a series of six graphs providing results on the V1 speed reading plus overall statics such as the number of records and percentage of vehicles travelling over the speed limit. It also provides the user several functions such as defining a time interval for the graphs and refining a subset of data It doesn't however provide detailed analysis of the V2 speed reading.

The analysis software does allow the raw data to be exported into a comma delimited space file (CSV) which includes the V1 and V2 speeds plus date and time stamp. From the raw data, the sites have been analysed by developing a series of graphs and statistical measures comparing each record's V1 and V2 speeds. The V1 and V2 speeds allows measurements and statistics not just by all vehicles passing the sign, but more importantly by the difference between the vehicle's V1 speed reading to the V2 speed reading and thus to be able to gauge the sign's effectiveness.

Results for Program Round by Round

The portable speed warning signs have been operational since November 2013, and as at the end of March 2015, the 26 signs have been moved around Brisbane 175 times. Four of these sites had no data due to a sign fault. The sites are spread across 106 suburbs within Brisbane City Council as shown in the figure included at Appendix A. Based on the 171 sites, Table 5.1 below provides a high level summary of result for the program round by round and as a total.

Table 5.1 – Program Results Round by Round

Statistic	Round							
	1	2	3	4	5	6	7*	Total
Total number of vehicle trips (,000)	2,361.7	2,844.3	4,043.6	3,618.7	3,194.8	6,731.0	2,331.3	**25,125.4**
Reduction of average speed of all vehicles (km/hr)	5.7	4.5	4.8	5.7	4.6	5.2	6.5	**5.2**
Reduction of average speed of vehicles with V1 speeds > the speed limit (km/hr)	10.1	8.6	9.3	9.2	9.5	9.4	10.0	**9.5**
Percentage total vehicles with V1 speeds > the speed limit (%)	29.3	15.4	18.1	26.3	20.6	22.4	24.5	**22.1**
Percentage total vehicles with V2 speeds > the speed limit (%)	10.9	6.2	7.6	11.4	8.9	8.4	8.2	**8.7**

*Note: * Data from seventh round is for 16 of the 26 sites. 10 sites are still to be moved and analysed as at end of Mar 2015.*

Table 5.1 shows that the program has shown a marked decrease for vehicles travelling over the speed limit as a consequence of been advised of their entering speed from 22.1% of the 25.1Million to 8.7%. The program has delivered a reduction of average speed for vehicle travelling over the speed limit of 9.5km/hr across all sites since the program began.

Summary of Sites within the Program

A breakdown of the number of sites and vehicles by road hierarchy and speed limit is shown in Table 5.2. *Table 5.2 – Number of Sites and Vehicles by Road Hierarchy and Speed Limit*

Road Hierarchy	Speed Zone					
		40km/hr	50km/hr	60km/hr	70km/hr	Total
Arterial	Number of Sites	0	0	8	1	**9**
	Number of Vehicles (,000)	0.0	0.0	1,951.5	214.8	**2,166.3**
Suburban	Number of Sites	2	4	34	1	**41**
	Number of Vehicles (,000)	430.1	768.2	7,298.0	204.9	**8,701.2**
District	Number of Sites	6	42	27	1	**76**
	Number of Vehicles (,000)	599.1	5,849.8	4,493.0	120.5	**11,062.4**
Neighbourhood	Number of Sites	4	40	1	0	**45**
	Number of Vehicles (,000)	438.4	2,684.3	72.8	0.0	**3,195.4**
Total	**Number of Sites**	**12**	**86**	**70**	**3**	**171**
	Number of Vehicles (,000)	**1,467.6**	**9,302.3**	**13,815.3**	**540.3**	**25,125.4**

Table 5.2 show that the program has a diverse range of sites with the four main site type's account for 143 sites (83.6%) of the 171 sites with 20.3Million vehicles (80.8%) as follows:

- District at 50km/hr – 42 sites (24.6%) with 5,849,800 vehicles (23.3%),

- Neighbourhood at 50km/hr – 40 sites (23.4%) with 2,684,300 vehicles (10.7%),
- Suburban at 60km/hr – 34 sites (19.9%) with 7,298,000 vehicles (29.0%),
- District at 60km/hr – 27 sites (15.8%) with 4,493,000 vehicles (17.9%).

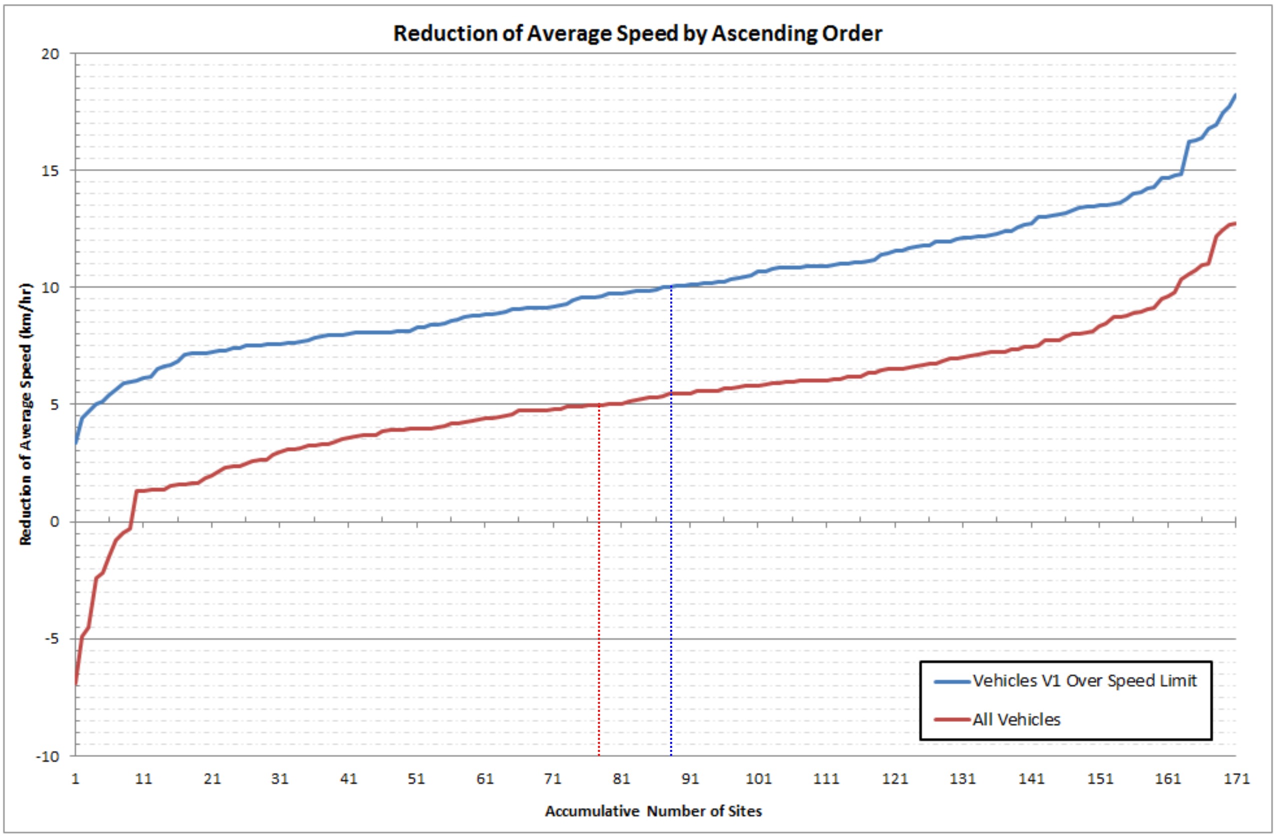
Results for Reduction of Average Speed

The reduction of average speeds for all vehicles and vehicles entering the sign radar range over the speed limit are shown in Figure 5.5 in ascending order.

Figure 5.5 results show all sites are effective at reducing speeds for vehicles with V1 over the speed limit with a range of 3.4km/hr to 18.2km/hr. 50% of the sites show a reduction of the average speed of 10km/hr or greater. 45% of the sites show a reduction of the average speed of 5km/hr or greater.

A few sites had a negative value as these sites had the large majority vehicles still accelerating as they approached the sign. This was as the sign was either too close to the start of the street or just after a side street with a high volume turning to the sign.

Figure 5.5 – Reduction of Average Speed by Ascending Order



Further figures with results of reduction of average speeds by various characteristics are included at Appendix B to determine if any sites are more the effective than others. These figures shows results only for vehicles entering the sign radar range over the speed limit. From these figures the following observations can be concluded:

- by volume the signs shows a spread of results, but they provide slightly better reduction of average speeds for sites with lower volume of vehicles (see Figure B.1),
- the sign are effective for all road hierarchies are effective at reducing speeds. Additionally, approximately half the sites for each road hierarchies have a reduction of average speed of 10km/hr or greater (see Figure B.2),
- the sign are effective for all speed limits at reducing speeds. Approximately half the sites for each speed limit have a reduction of average speed of 10km/hr or greater (Figure B.3).

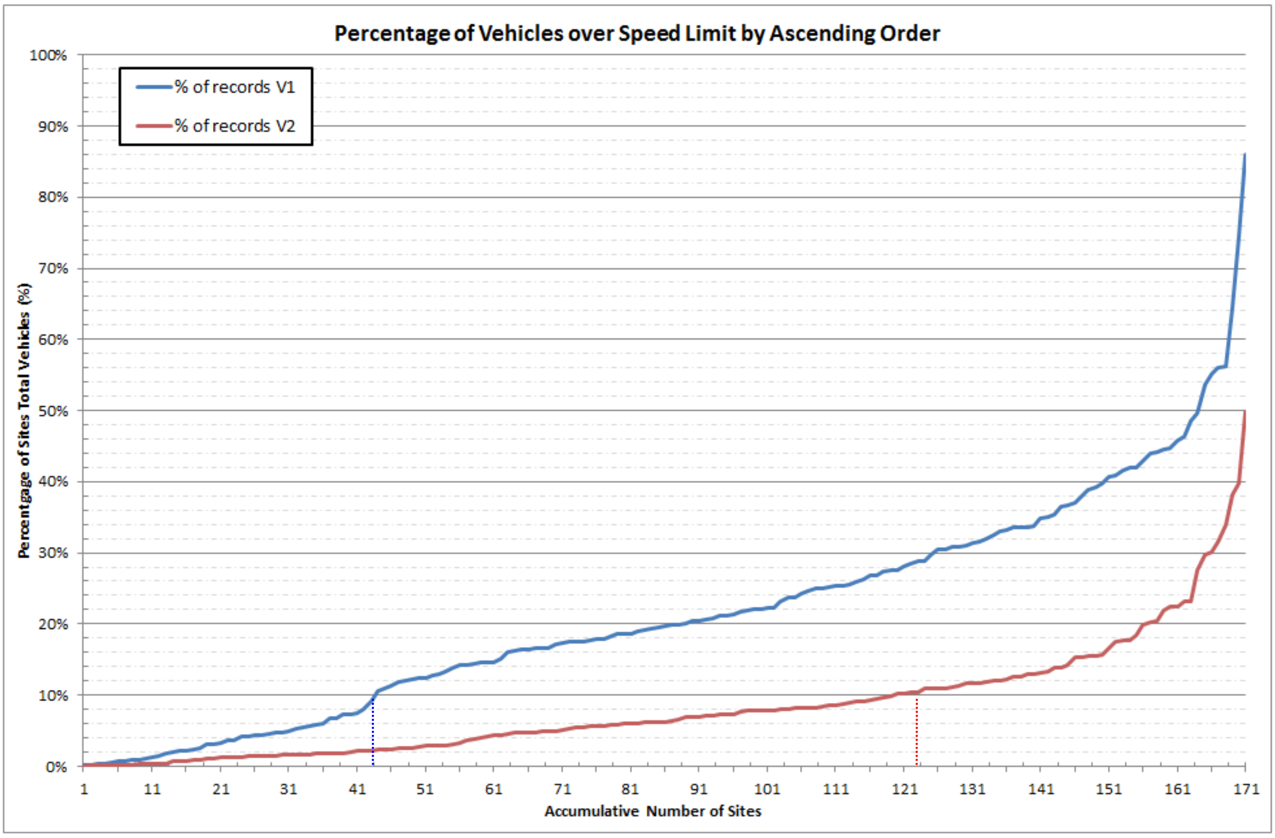
Results of Percentage Speeding

Whilst Section 5.3 results show the portable speed signs are effective in reducing the average speed, the other parameter that can be analysed is the percentage of vehicles over the speed limit at both V1 and V2.

The percentage of vehicles over the speed limit at V1 and V2 are shown in Figure 5.6 in ascending order.

Figure 5.6 shows 75% of sites have 10% or more of vehicles over speed limit at V1 and only 30% of sites at V2. Therefore, the signs are not only effective at reducing speeds but also increasing the number vehicles adhering to the speed limit.

Figure 5.6 – Percentage of Vehicles Over Speed Limit by Ascending Order



Further figures with results of percentage speeding by various characteristics are included at Appendix C to determine if any sites are more the effective than others. From these figures the following observations can be concluded:

- by volume the signs shows a spread of results for both the V1 and V2 records, but both linear trend lines for provide an indication of slightly lower percentage of vehicles speeding for sites with lower volumes (see Figure C.1),
- the sign are effective for all road hierarchies at reducing the percentage of vehicles over the speed limit. Approximately 65% to 75% of sites for each road hierarchy have only 10% of vehicles V2 records over the speed limit (see Figure C.2),
- the sign are effective for all speed limits at reducing the percentage of vehicles over the speed limit. Approximately 50% to 70% of sites with 40 to 60 speed limits have only 10% of vehicles V2 over the speed limit. The 70km/hr sites (3) all had less than 10% of vehicles V2 records over the speed limit (see Figure C.3).

Results for School Zones Sites

Of the 171 sites, 15 sites are within a school zone. Table 5.3 below provides a high level summary of result for records at school times. Note all sites had school zone times of 7-9am and 2-4pm.

Table 5.3 – Program Results for School Zones at School Times

Static	Total
Total number of vehicle trips	**390,014**
Reduction of average speed of all vehicles (km/hr)	**4.6**
Percentage total vehicles with entering speed over the speed limit (%)	**32.0**
Percentage total vehicles with final speed over the speed limit (%)	**16.5**
Reduction of average speed of vehicles with entering speed over the speed limit (km/hr)	**8.6**

A breakdown of the number of sites and vehicles by road hierarchy and speed limit for the 15 sites within School Zones is provided in Table 5.4.

Table 5.4 – Number of Sites and Vehicles by Road Hierarchy and Speed Limit within School Zones

Road Hierarchy		Speed Zone				
		40km/hr	50km/hr	60km/hr	70km/hr	Total
Arterial	Number of Sites	0	0	3	0	**3**
	Number of Vehicles	0	0	303,010	0	**303,010**
Suburban	Number of Sites	0	0	3	0	**3**
	Number of Vehicles	0	0	508,296	0	**508,296**
District	Number of Sites	1	4	4	0	**9**
	Number of Vehicles	120,568	468,737	850,636	0	**1,439,941**
Neighbourhood	Number of Sites	0	0	0	0	**0**
	Number of Vehicles	0	0	0	0	**0**
Total	**Number of Sites**	**1**	**4**	**10**	**0**	**15**
	Number of Vehicles	**120,568**	**468,737**	**1,661,942**	**0**	**2,251,247**

The results for school zone sites are similar to the sections above, that is, the portable speed warning signs are effective at reducing speeds and increasing the number of vehicles adhering to the speed limit for all road hierarchy, speed limits and number of vehicles per day. A series of figures for school zone sites are included at Appendix D.

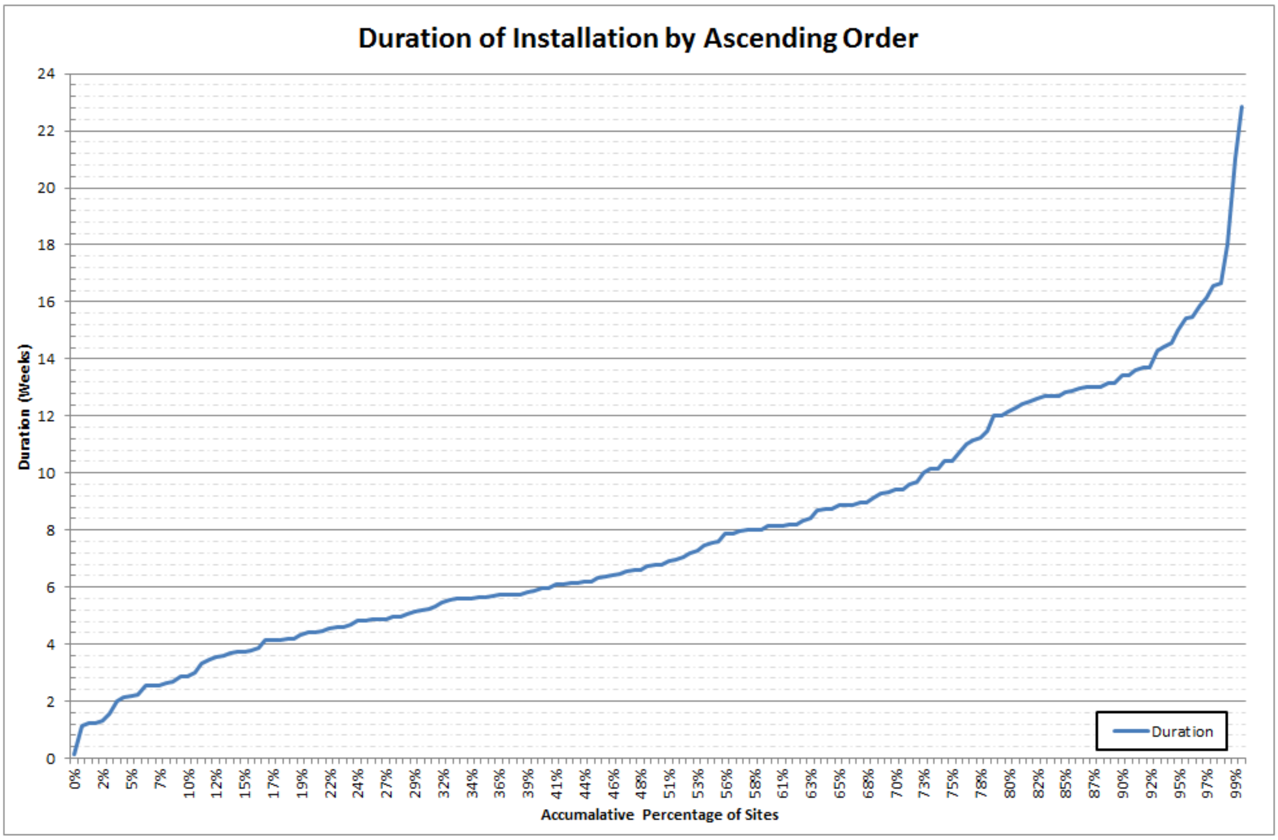
Results by Duration Installed

As part of the program development, research was undertaken which showed results of electronic speed signs in terms of speed reductions and compliance to the speed limit improved over time. In fact, some studies showed locations with signs installed for several years with nearly all vehicles adhering to the speed limit. Despite the signs being warning signs and not enforceable, motorists observed the signs messaging over time.

As Council is installing the portable speed warning signs for a minimum of one month duration at sites, analysis is being completed assessing the results week by week. This is to understand what duration is required to allow the speed warning sign to have a positive effect on motorists. Additionally, what duration does the sign show a change in terms of driver behaviour not just a reaction to the sign.

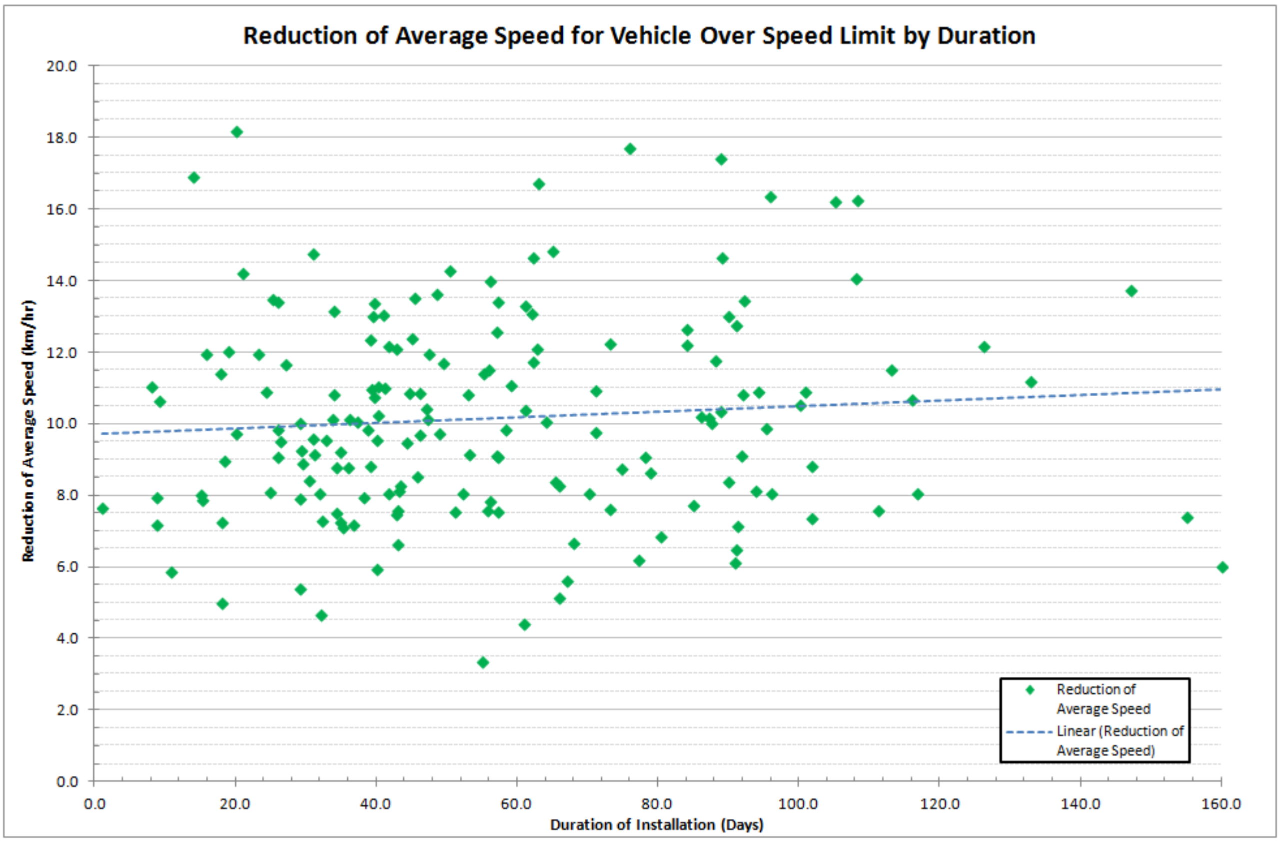
The duration of sign installation is shown in Figure 5.7 which shows an average duration of 8 weeks and maximum of 23 weeks.

Figure 5.7 – Duration of Installation by Ascending Order



The reduction of V1 to V2 average speeds by duration of sign installation is shown in Figure 5.8. Whilst Figure 5.8 shows a spread of results of reduction in average speeds, the linear trend line provides an indication of a slight increase in the reduction average speeds reducing over time.

Figure 5.8 – Reduction of Average Speed by Duration of Installation



The percentage of vehicles over the speed limit at both the V1 and V2 by duration of sign installation is shown in Figure 5.9.

Figure 5.9 – Percentage of Vehicles Speeding by Duration of Installation

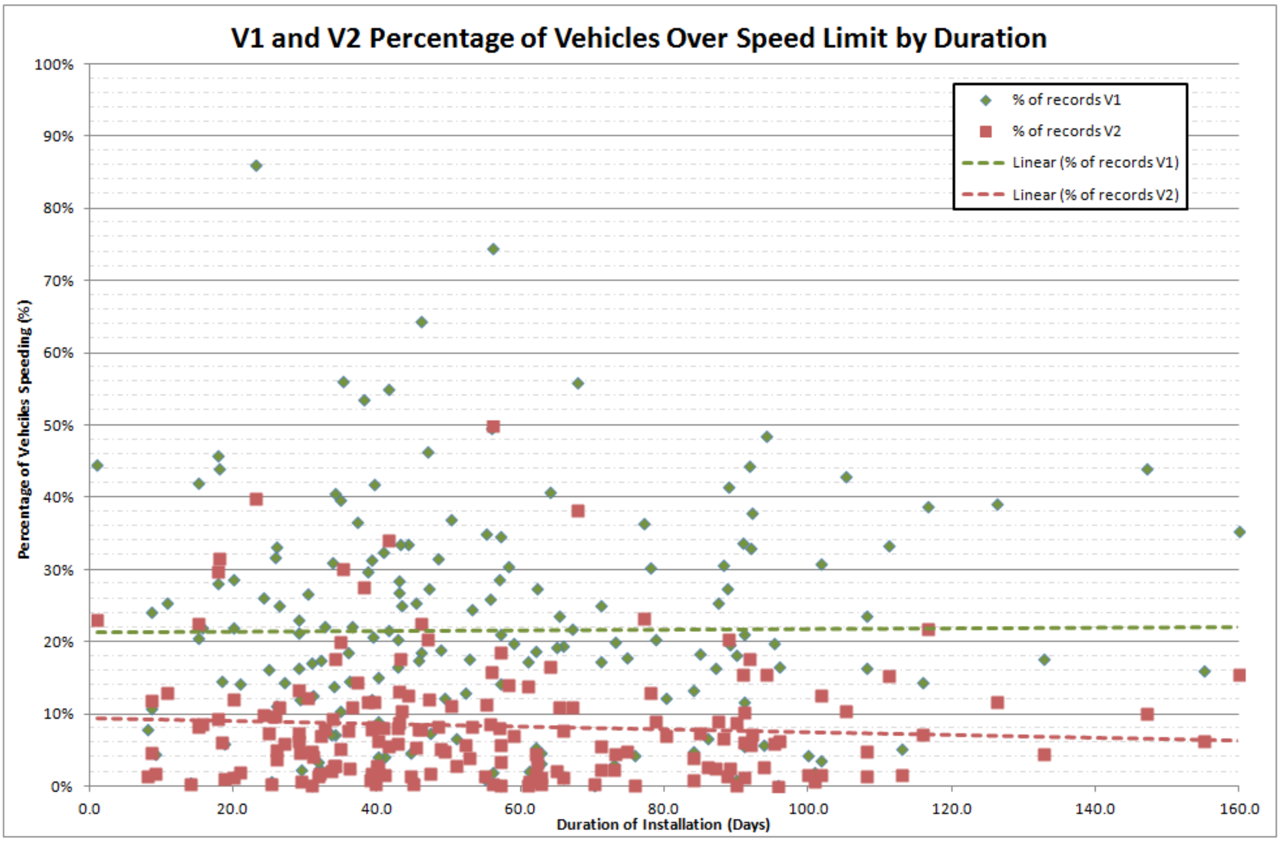
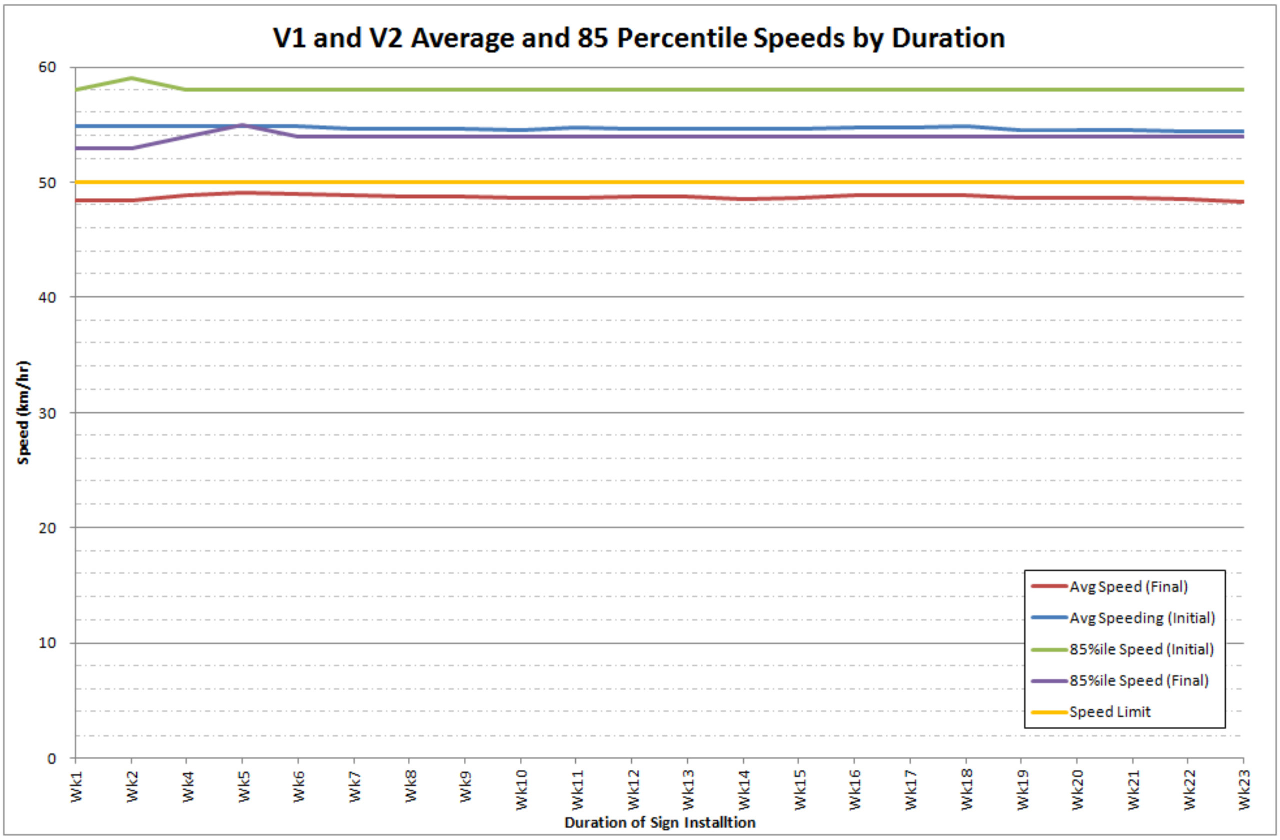


Figure 5.9 shows a spread of results for both the entering and exiting records. Whilst the linear trend line for the V1 records percentage of speeding shows a constant trend over duration of sign installation, the percentage of speeding for V2 records shows a slight decrease over duration of sign installation.

The two sites with the longest durations of installation have been assessed in more detail to further understand the results over longer durations of installation.

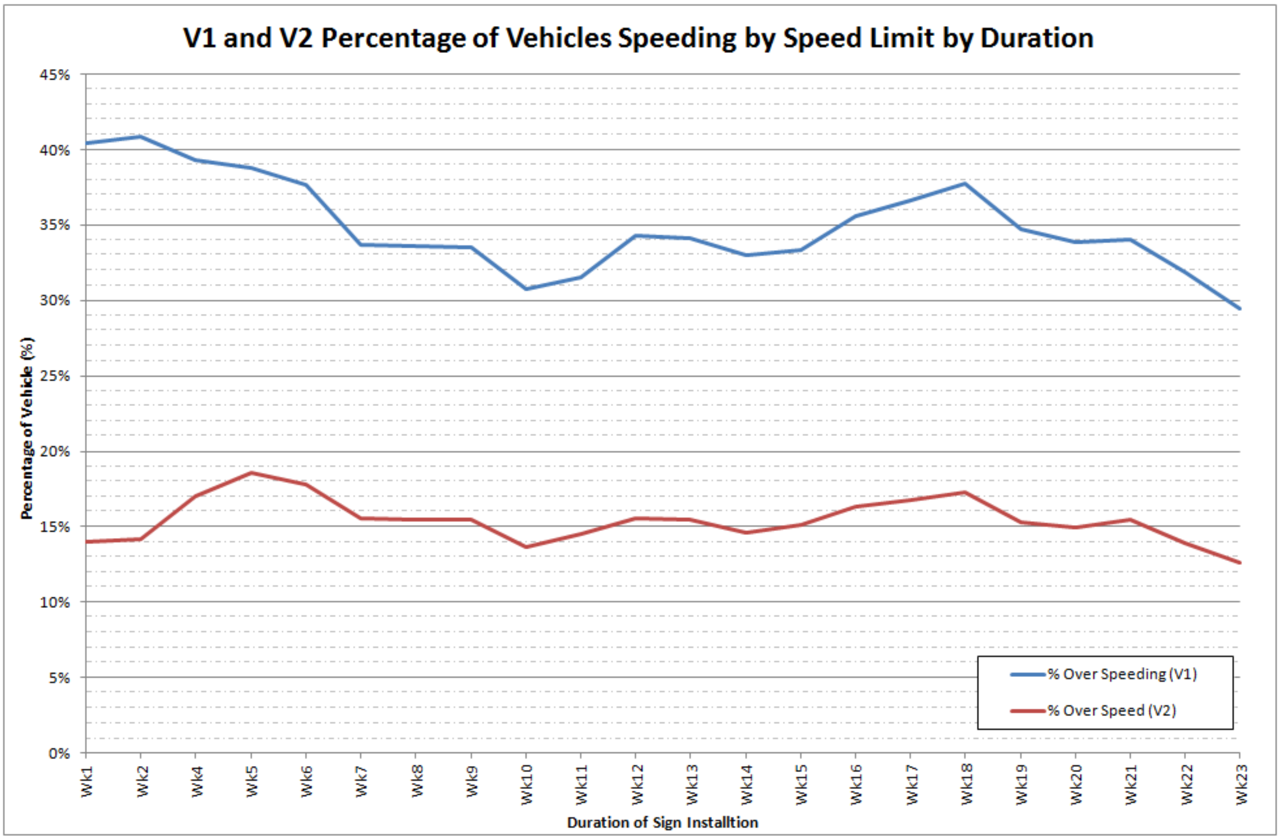
Site 1 is a street with a district hierarchy with a 50km/hr speed limit and non-school zone. It was installed for 160 days or 23 weeks and 6 days and had nearly 500,000 records pass it. Figure 5.10 shows average speed and 85th percentile speed for V1 and V2 week by week. The data shows fairly constant results week by week with both average speed and 85th percentile speed approximately 2km/hr less at week 23 compared to week 1.

Figure 5.10 – Site 1 Week by Week Vehicle Average and Percentile Speeds



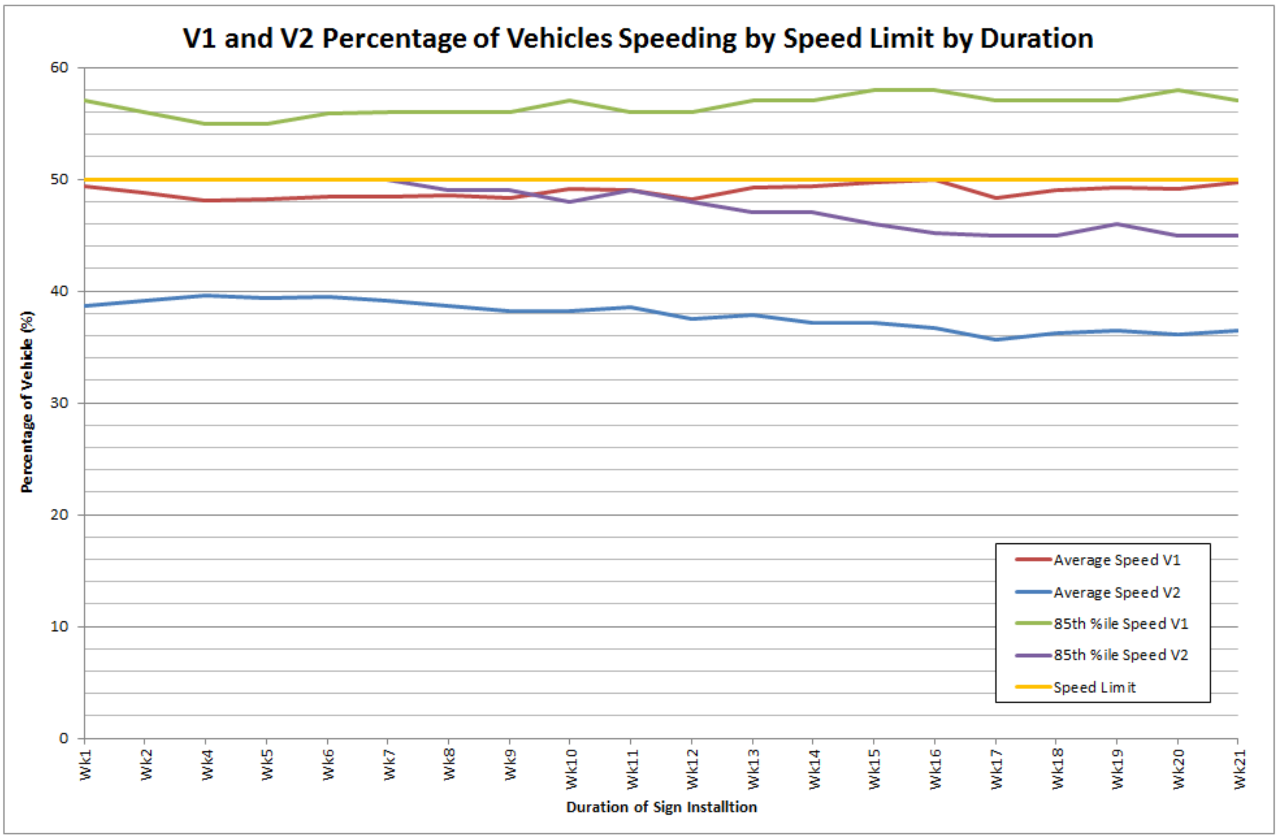
A week by week comparison of percentage of vehicles over the speed limit for both V1 and V2 records is shown in Figure 5.11. Figure 5.11 shows a reduction of slightly more than 10% of vehicles speeding for V1 speeds between week 23 and week 1 with only 1.5% reduction for V2 speeds. This data suggests that motorists are learning the speed limit of the street prior to the sign not just once seeing the sign, and/or changing their driving behaviour.

Figure 5.11 – Site 1 Week by Week Percentage of Vehicles Speeding



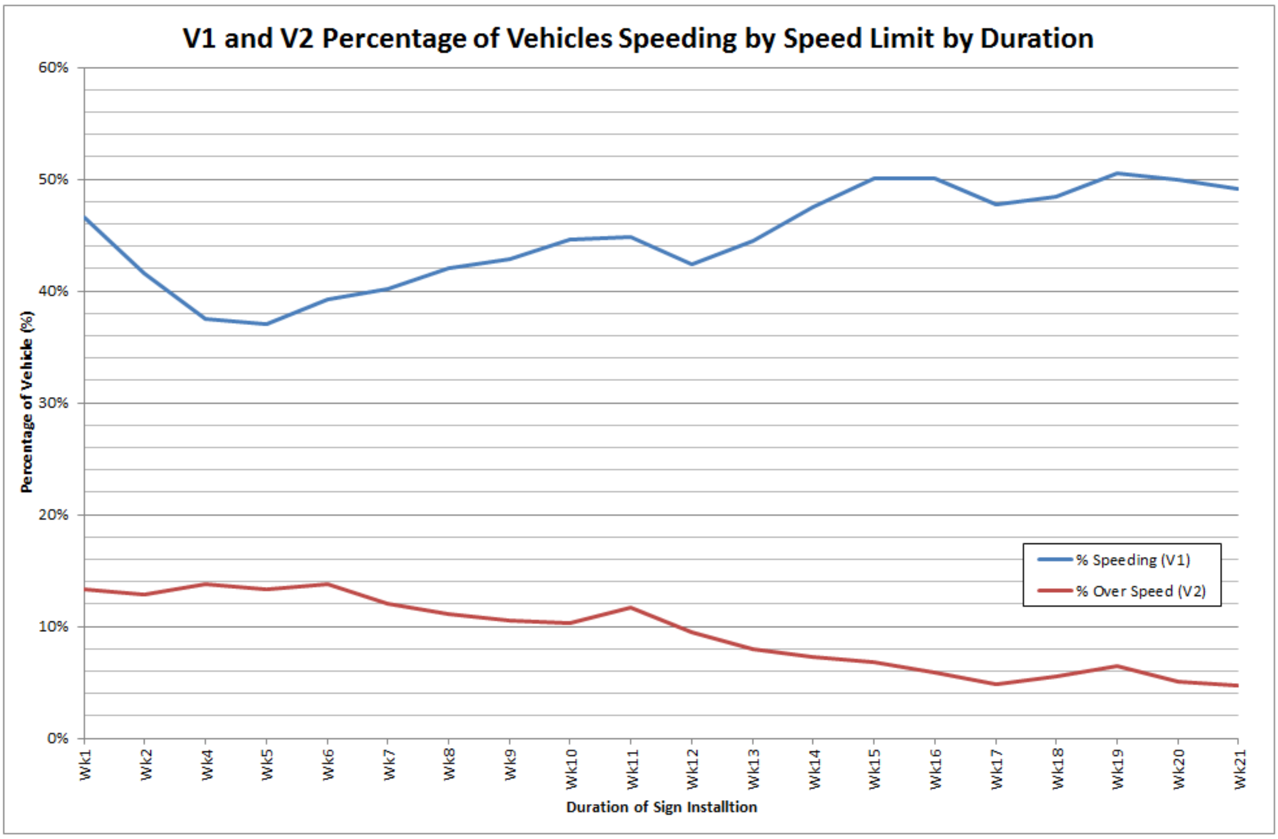
Site 2 is a street with a neighbourhood hierarchy with a 50km/hr speed limit and non-school zone. It was installed for 147 days or 21 weeks and had just over 100,000 records pass it. Figure 5.12 shows both V1 and V2 for the average speed and 85th percentile speed week by week. The data in Figure 5.12 shows fairly constant results week by week for V1 speeds but a reduction for V2 speeds in particular the 85th percentile speed of 5km/hr.

Figure 5.12 – Site 2 Week by Week Vehicle Average and Percentile Speeds



A week by week comparison of percentage of vehicles over the speed limit for both V1 and V2 records is shown in Figure 5.13. Figure 5.13 shows a slight increase for V1 speeds between week 23 and week 1 but an 8.7% reduction of V2 speeds. This data suggests that motorists are reacting better to the messaging of the sign, and/or changing their driving behaviour.

Figure 5.13 – Site 2 Week by Week Percentage of Vehicles Speeding



Conclusions

Brisbane City Council proactive approach of installing 26 portable speed warning signs has reduced vehicle speeds by an average of 5.2km/hr for all vehicles and 9.5km/hr for vehicles travelling above the speed limit at V1. The visual reminder has delivered a significant reduction in motorists travelling above the speed limit from 22.1% of 25.1Million vehicles to 8.7%.

The data from each site no matter what speed limit, road hierarchy, or school or non-school zone has shown a marked decrease in the number of motorists travelling over the speed limit as a consequence of being advised of their entering speed.

The analysis has shown the three primary conclusions as follows:

1. Effective in reducing speeds which increases the compliance of vehicles over the speed limit,
2. Effective at reducing speeds and increasing the number vehicles adhering to the speed limit for all types of sites no matter their road hierarchy, speed limit or if a school zone, and
3. Continual effectiveness of reducing speeds and percentage speeding whilst in place for at least 23 weeks.

Lessons Learnt and Next Steps

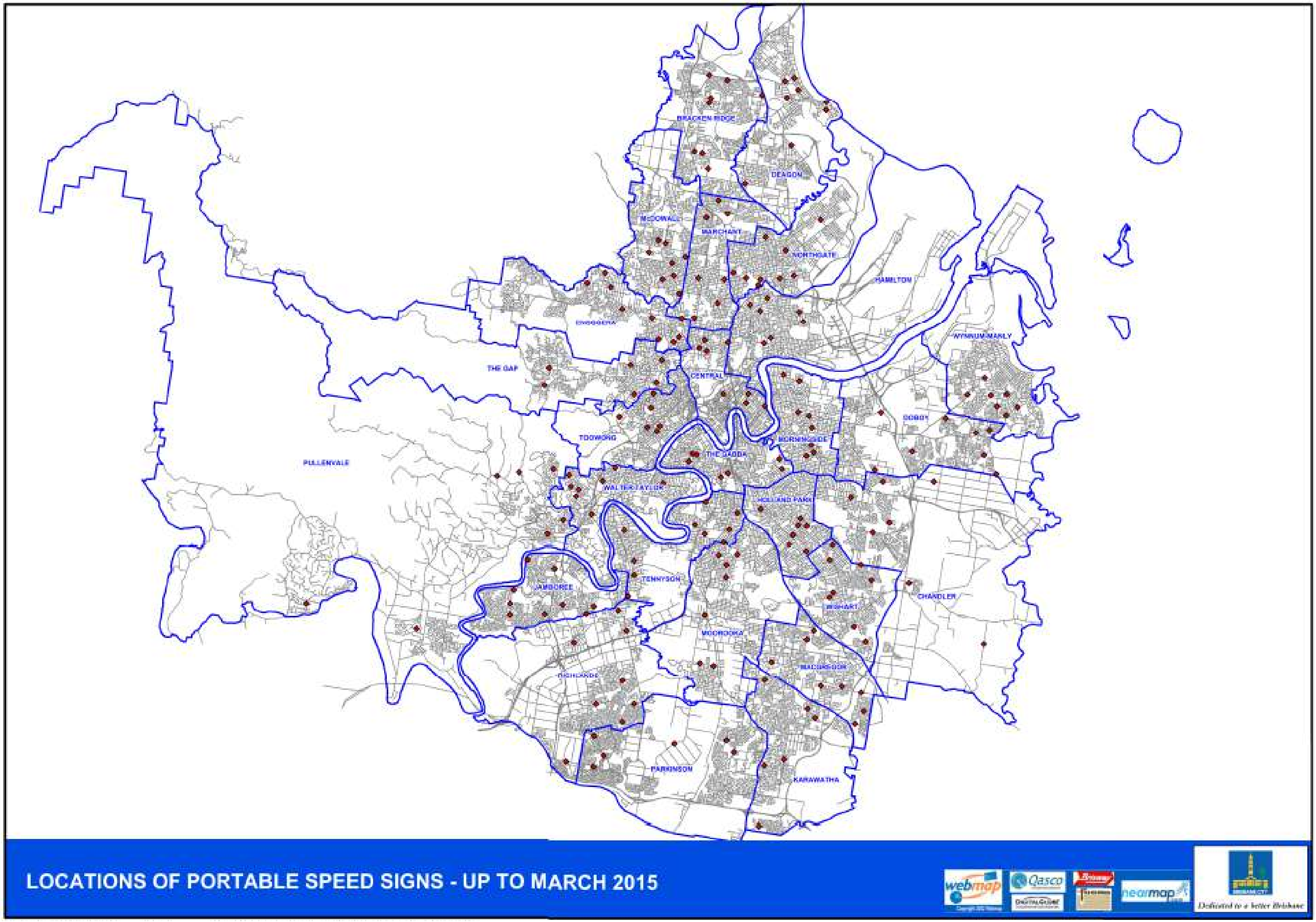
From managing the program over the last 17 months, the lessons learnt are broken down in three main areas:

1. Site assessment;
    - ensure adequate sight distance to read the sign,
    - ensure adequate sunlight for all months of the year, that is, in winter the sun is lower on the horizon,
    - ensure adequate distance from the start of street or from major traffic inflow to ensure vehicles are able to travelling at or above the speed and not still accelerating.
2. Community Consultation;
    - early engagement with local residents on proposed sign location/s as some residents feel a sense of ownership for their street.
3. Data Analysis;
    - most sites will provide a reduction in speed, just amount and the percentage of vehicles over the speed limit will vary,
    - the raw data allows detailed statistical analysis which provides very valuable information. Setting up this analysis can be quite time consuming so the process should be as automated as possible.

In terms of the next steps for the program the following are proposed:

- continued data analysis to determine most effective use of signs,
- potential alternative to use the signs as a permanent local area traffic management (LATM) device where speeding is the issue,
- provision of data to the Queensland Police Service.

Appendix A – Sites of Portable Speed Warning Signs within Brisbane City Council



Appendix B – Reduction of Average Speed for Vehicle Over the Speed Limit

Figure B.1 – Reduction of Average Speed by Volume

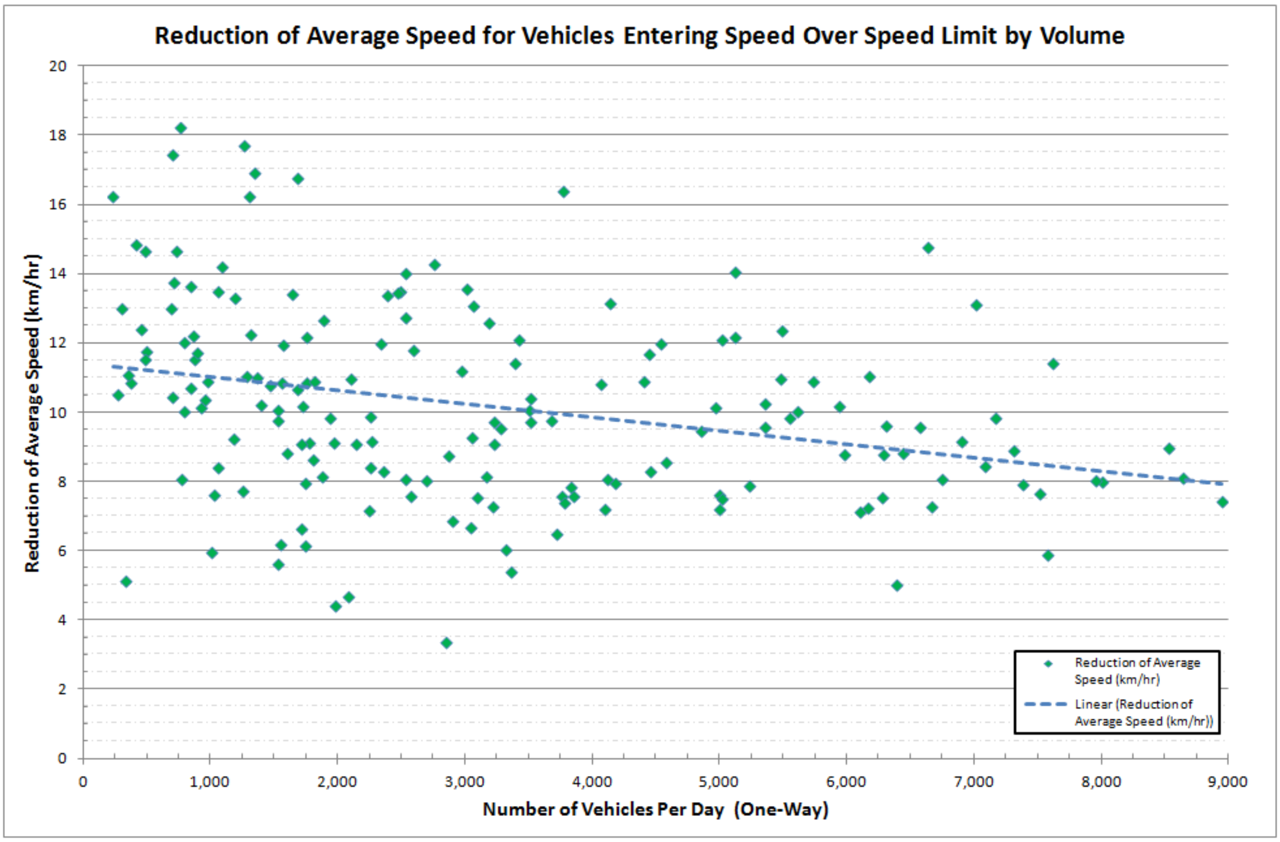


Figure B.2 – Reduction of Average Speed by Road Hierarchy

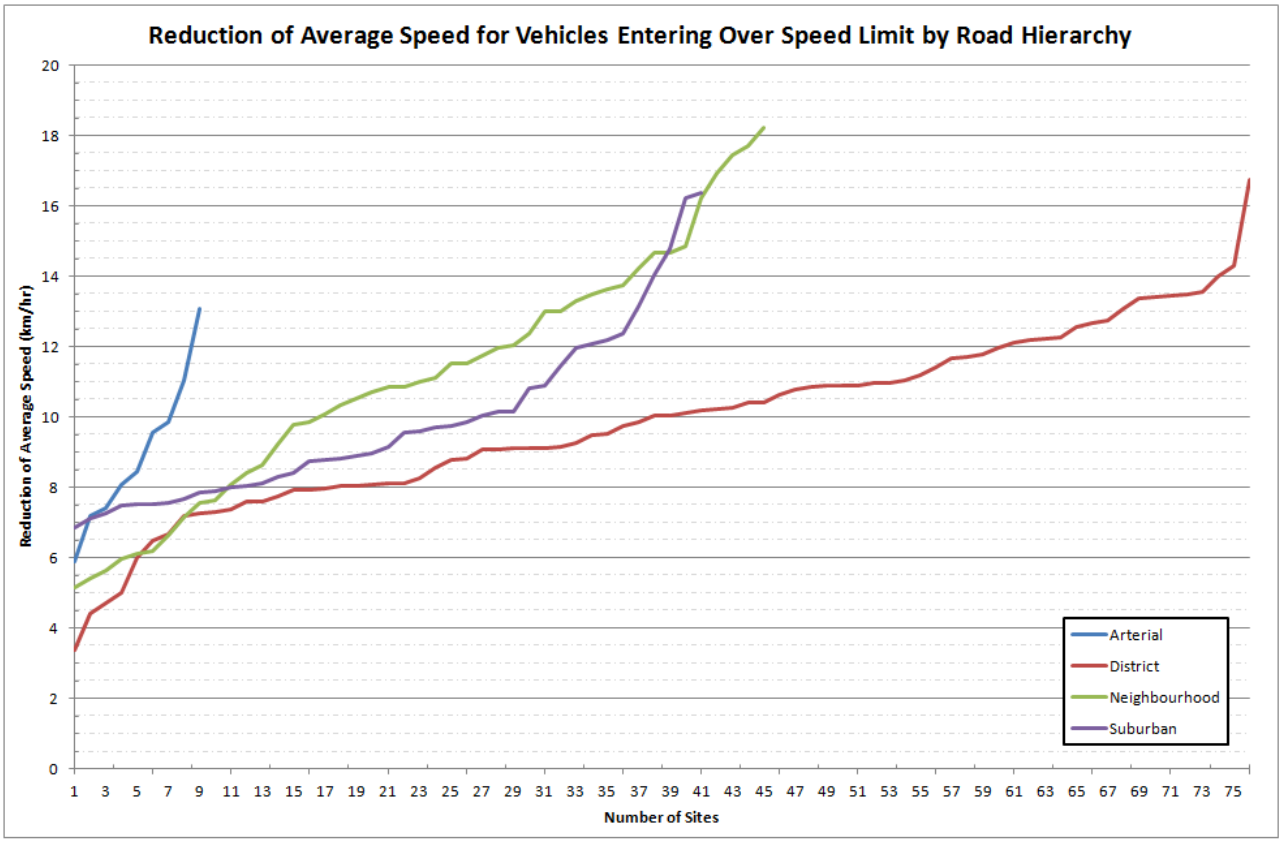
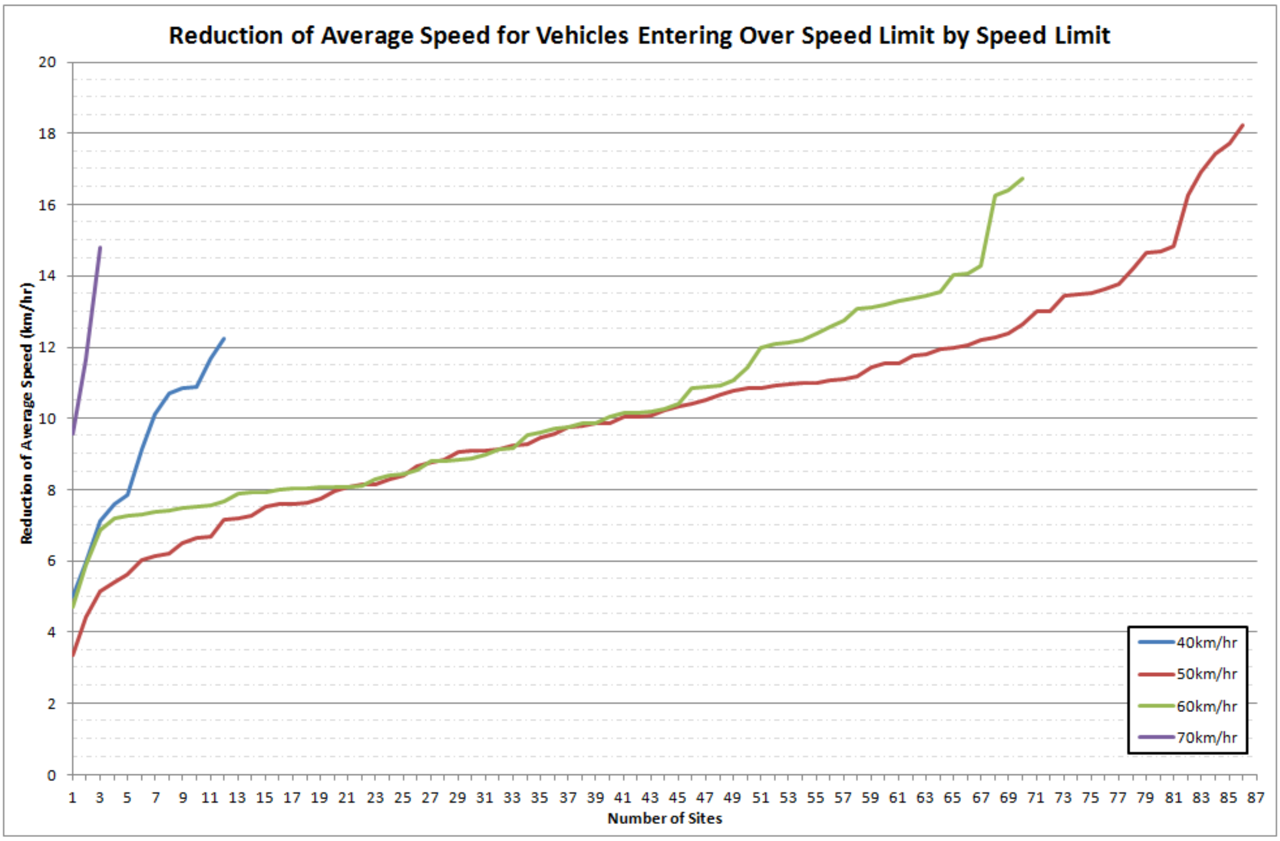


Figure B.3 – Reduction of Average Speed by Speed Limit



Appendix C – Percentage of Vehicles Speeding

Figure C.1 – Percentage of Vehicles Speeding by Volume

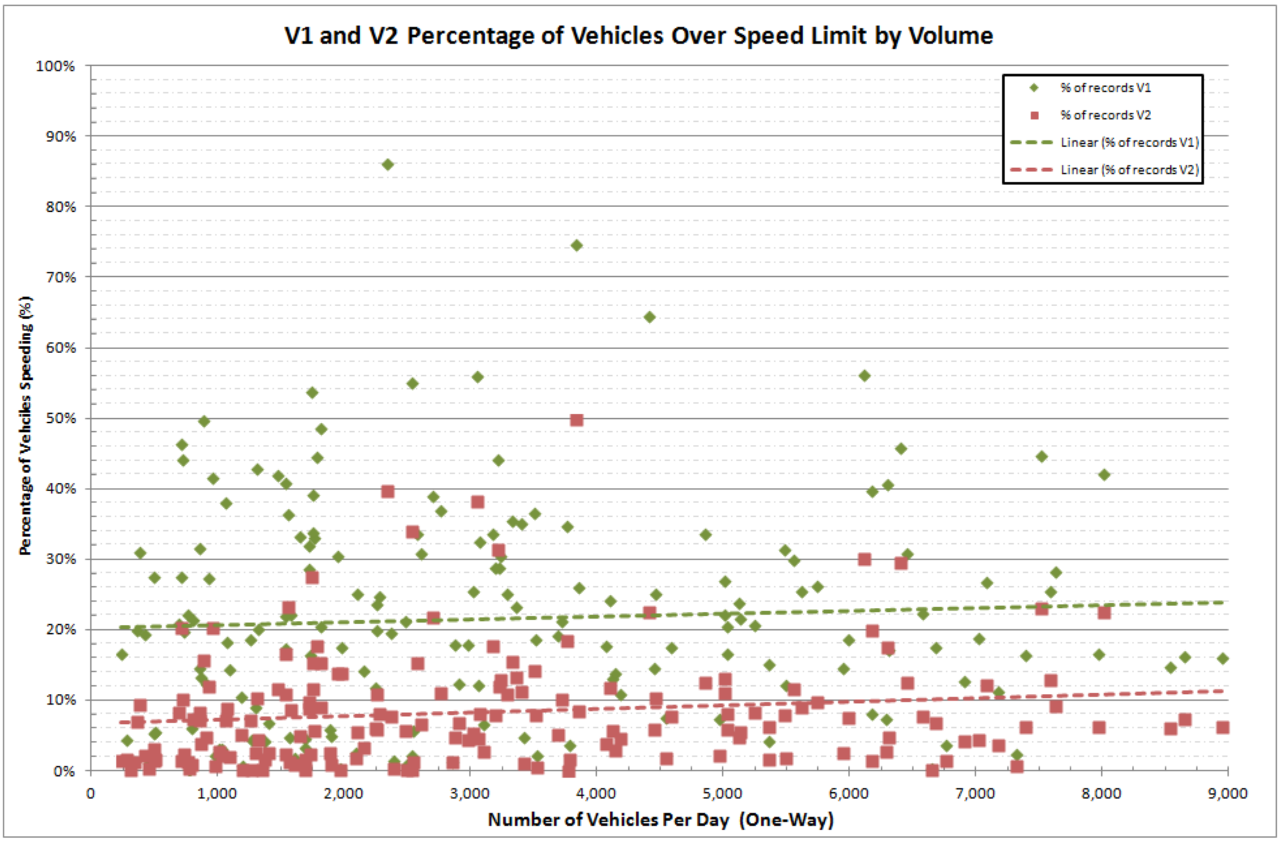


Figure C.2 – Percentage of Vehicles Speeding by Road Hierarchy

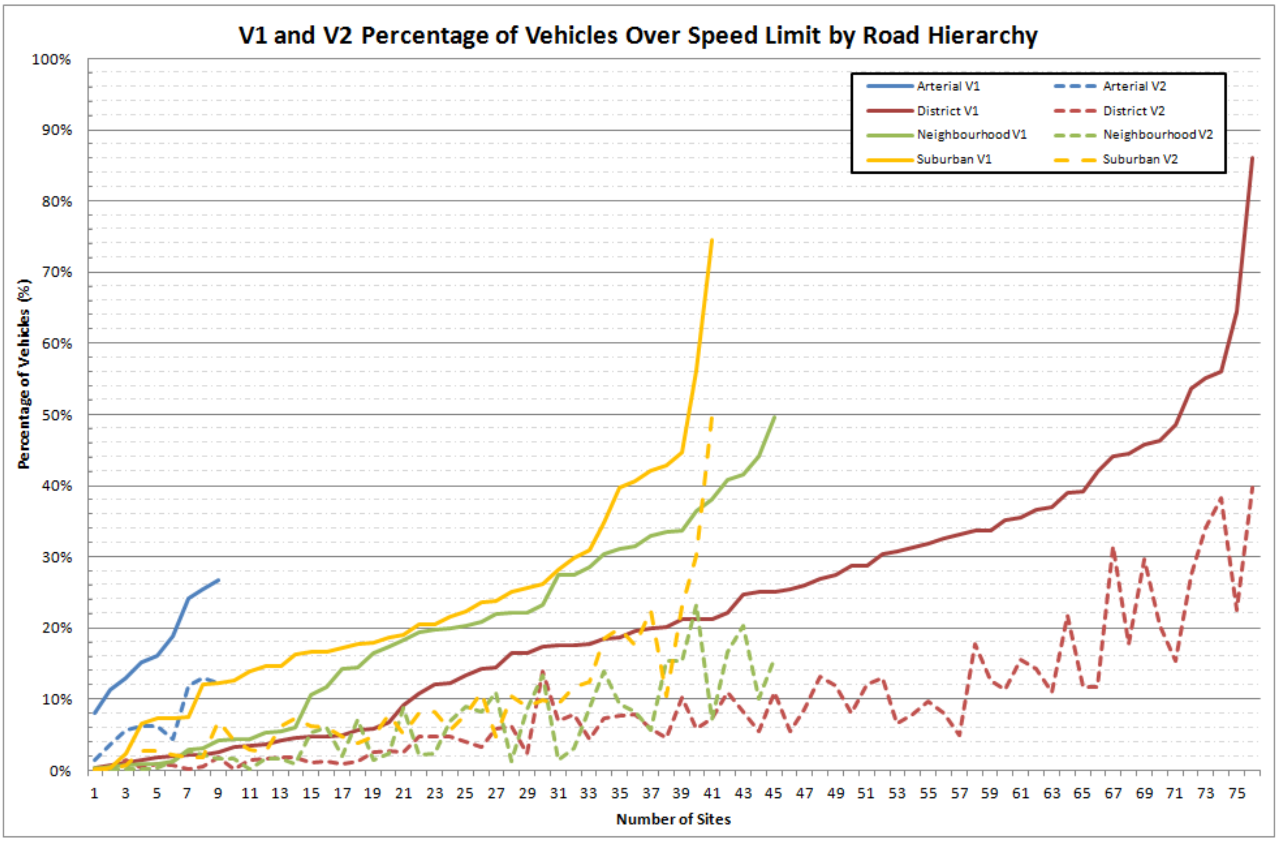
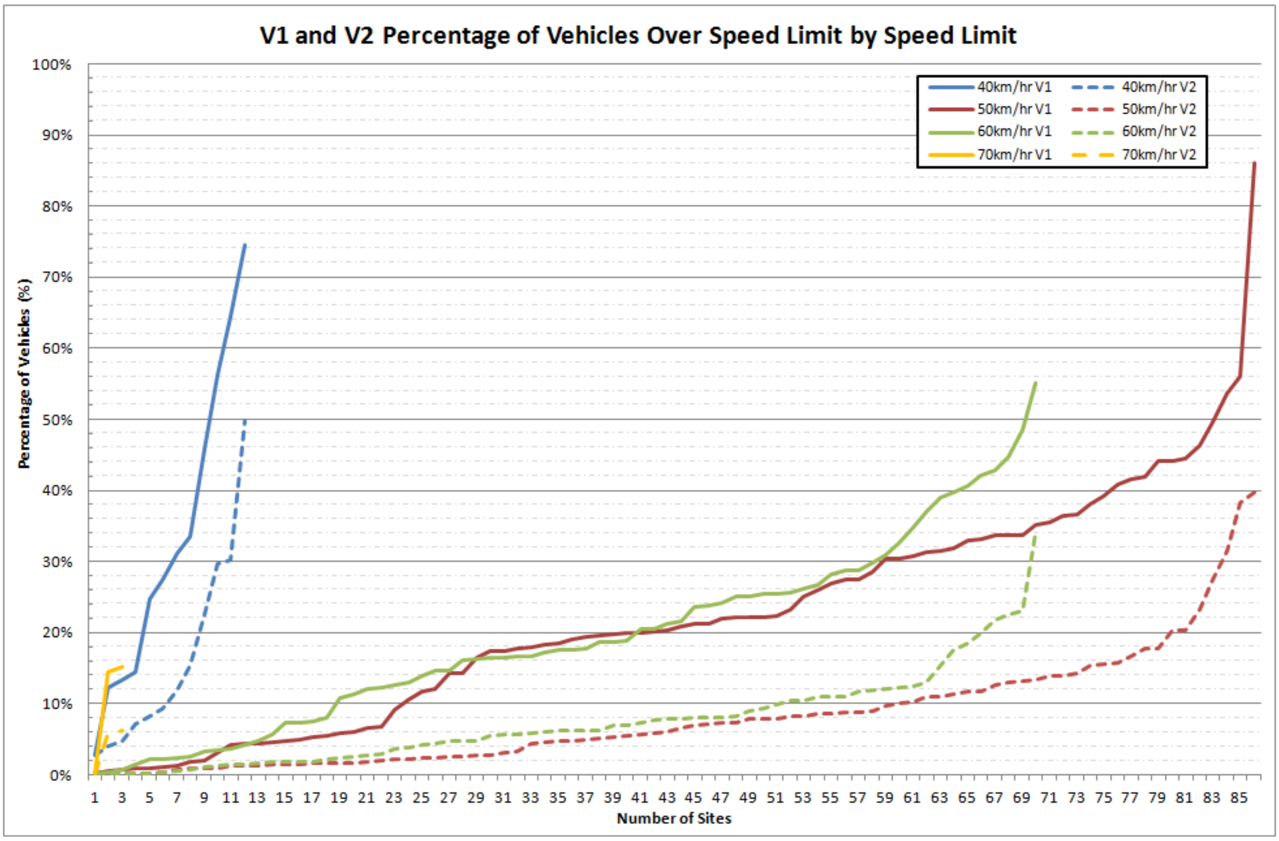


Figure C.3 – Percentage of Vehicles Speeding by Speed Limit



Appendix D – Figures of Results for School Zone Sites

Figure D.1 – Reduction of Average Speed During School Times

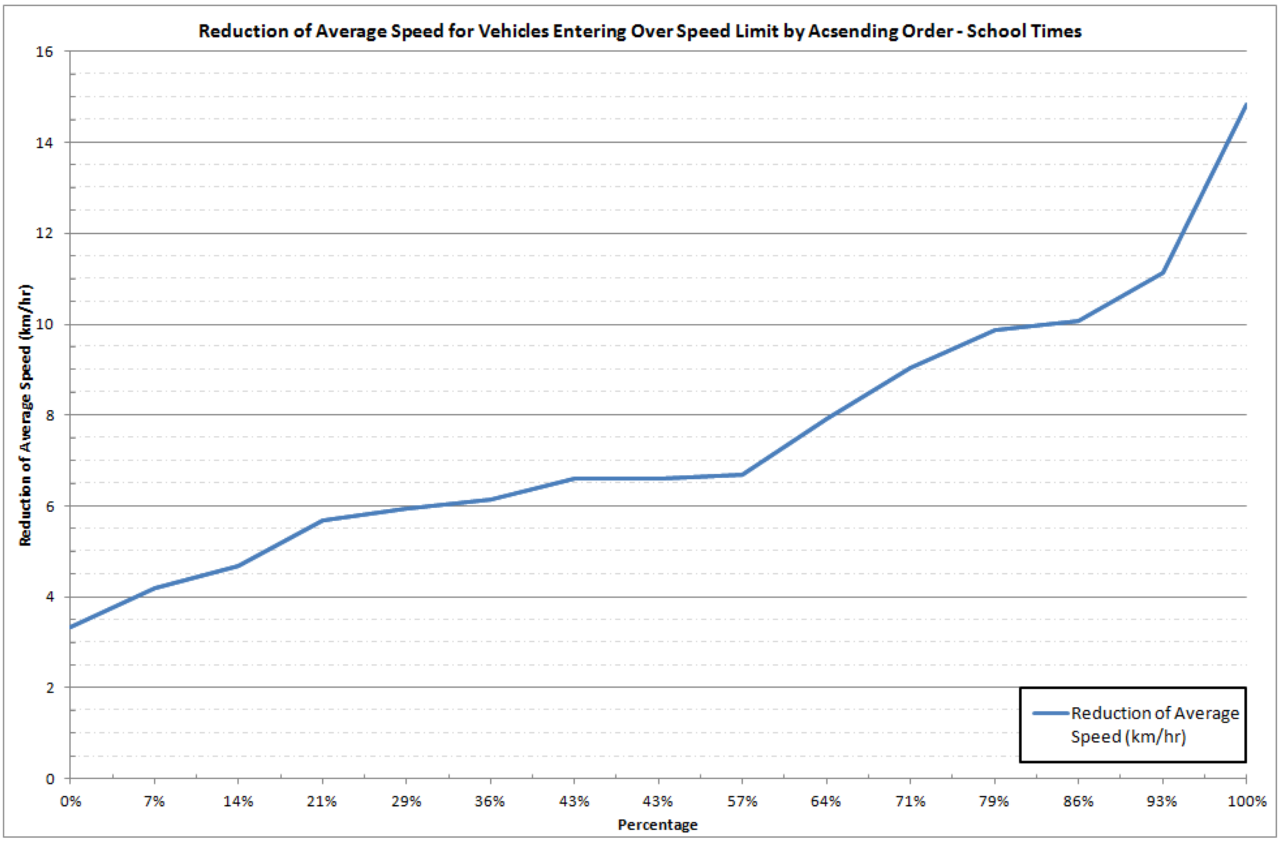


Figure D.2 – Reduction of Average Speed by Volume During School Times

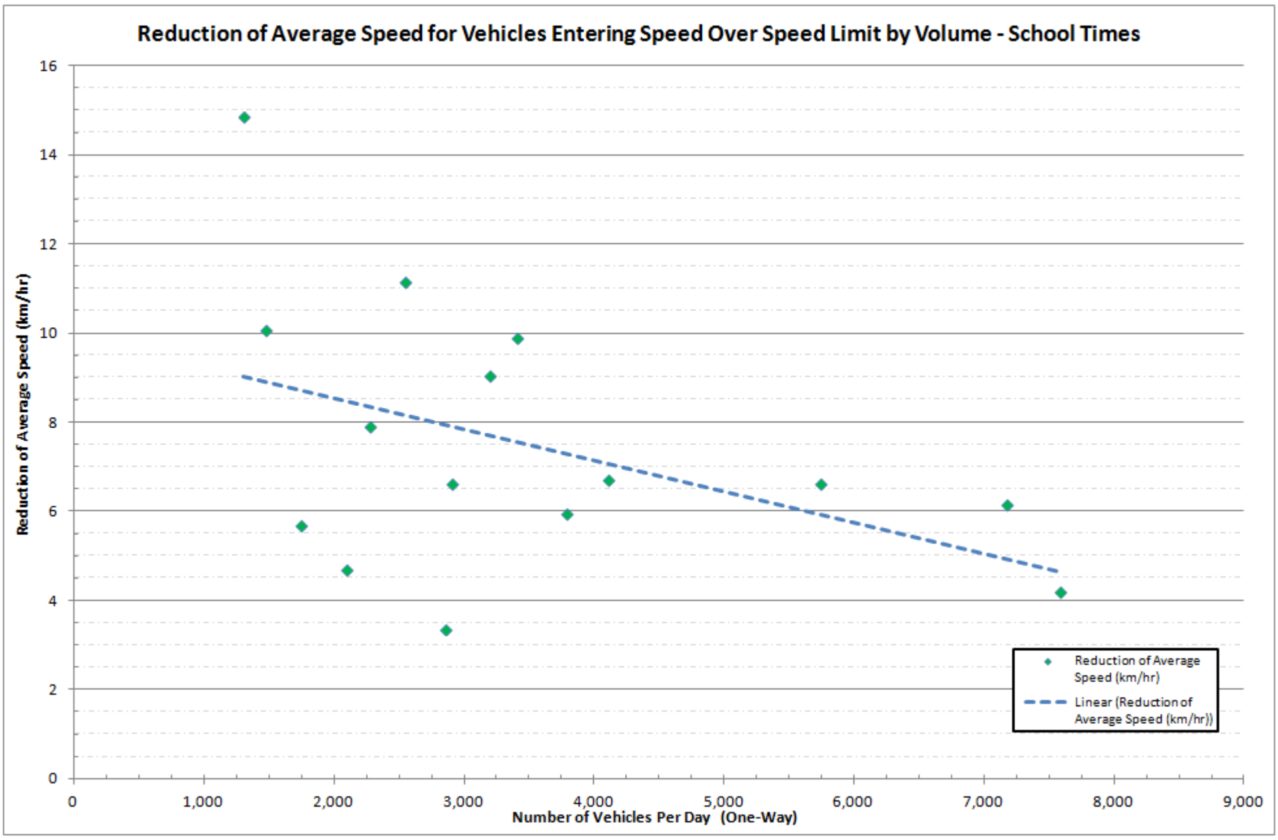


Figure D.3 – Reduction of Average Speed by Road Hierarchy During School Times

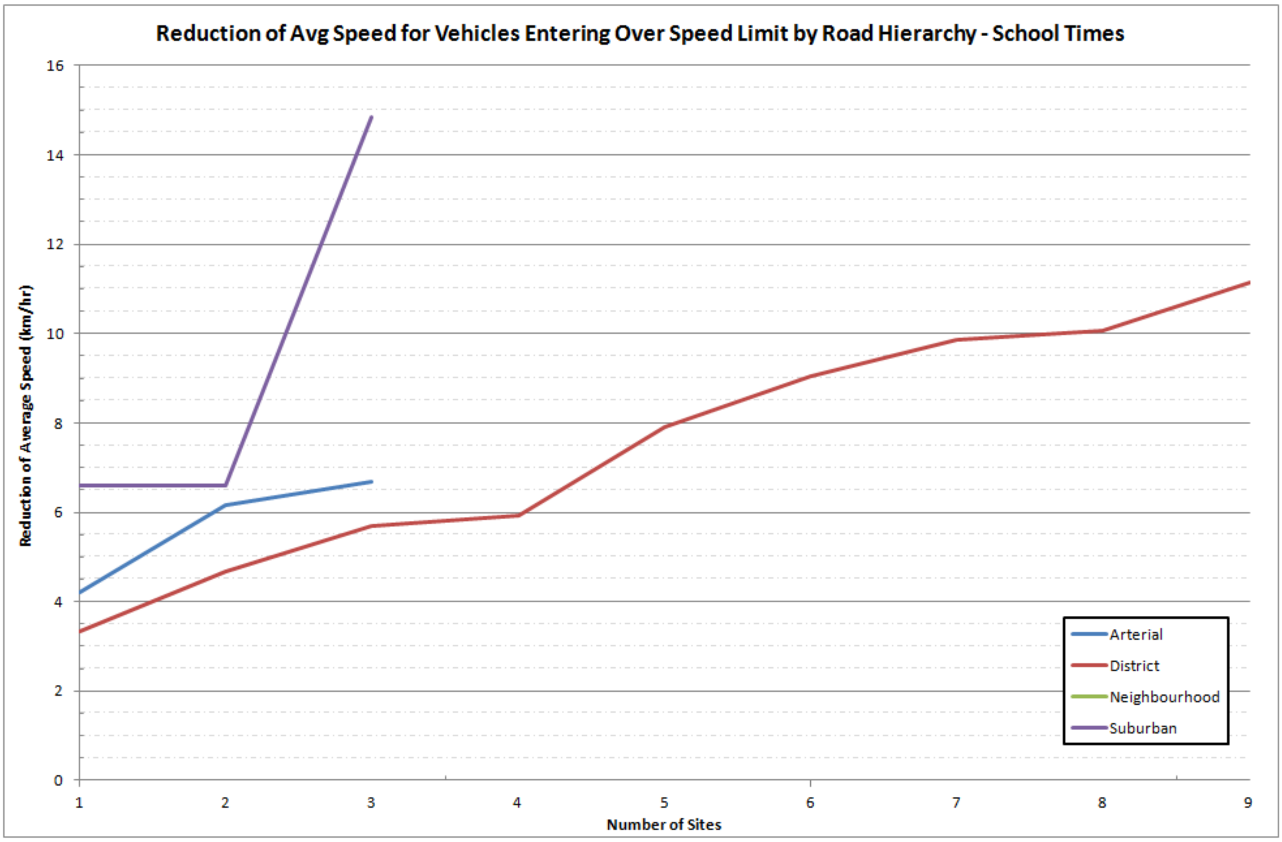


Figure D.4 – Reduction of Average Speed by Speed Limit During School Times

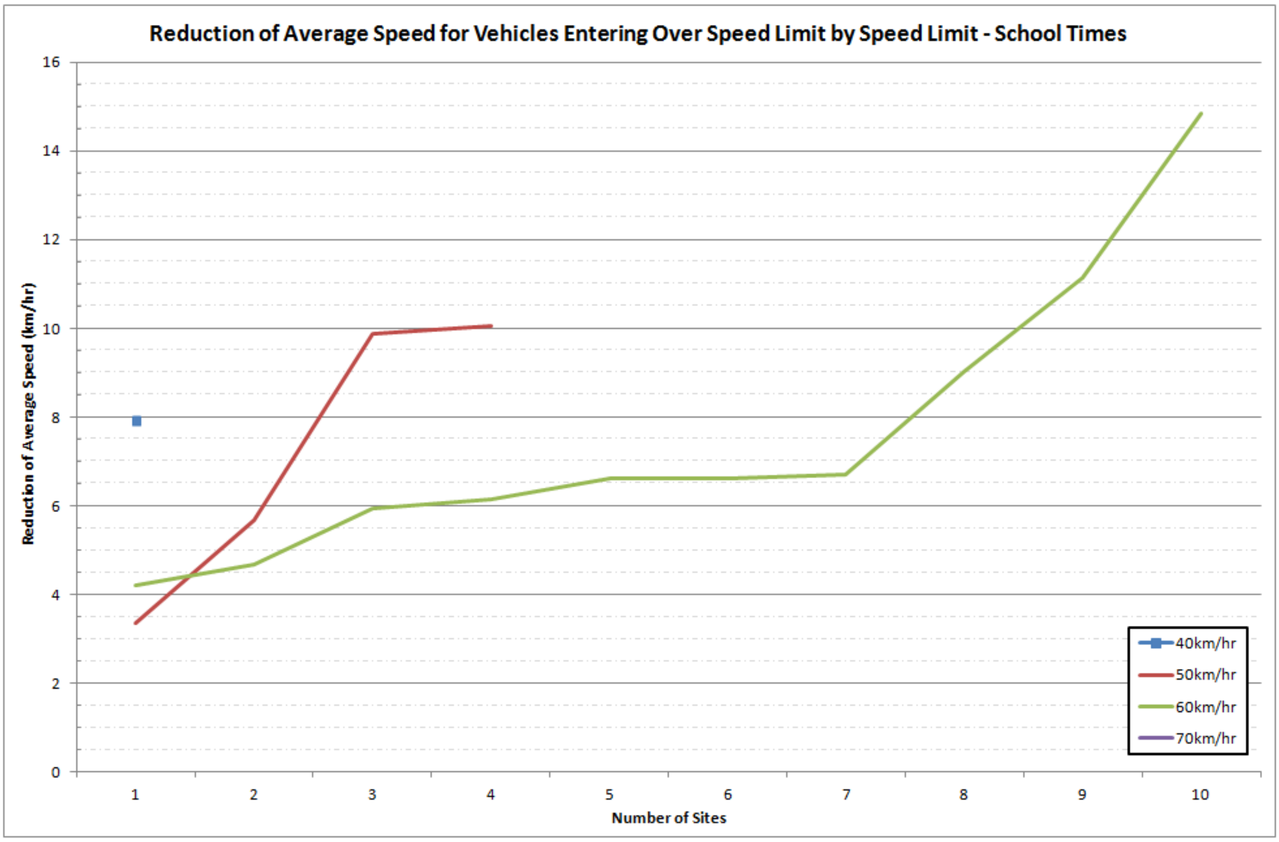
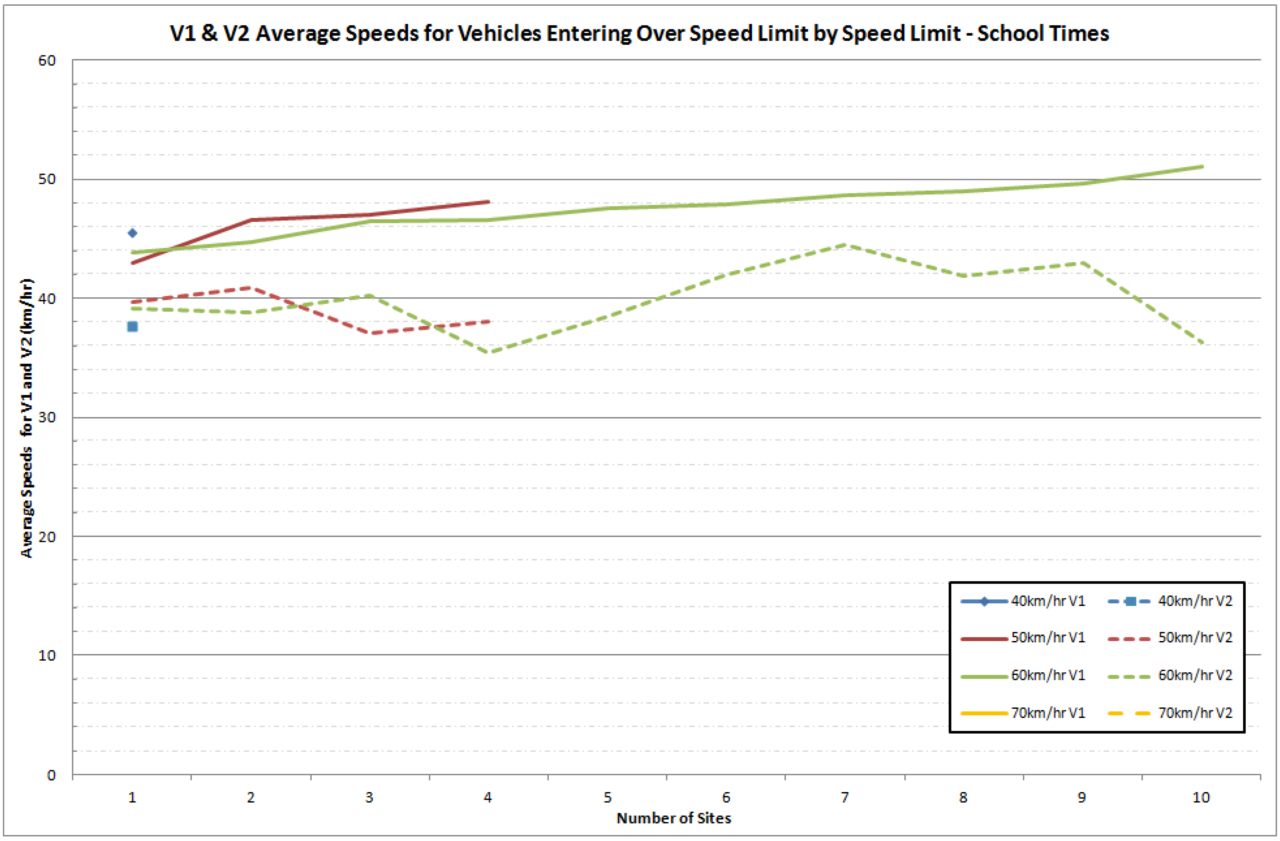


Figure D.5 – Comparison of Average Speeds for V1 & V2 by Speed Limit



Heavy Vehicle Driver Fatigue - Evidence-Based Policy Making

Marcus Burke, James Williams and Dr. Nick Fischer[1]

National Transport Commission, Australia

Abstract

The presentation introduces a new National Transport Commission project, undertaken in collaboration with the National Heavy Vehicle Regulator, to develop a national framework to collect and analyse fatigue data by the end of 2016.

The presentation highlights historic challenges associated with reforms of the national heavy vehicle fatigue regulations and in particular the need for an improved evidence-base before further amendments of fatigue laws are considered. For example, agencies today are collecting enforcement and crash investigation data using different processes and formats. This limits opportunities to collate and compare meaningful fatigue data and an initial step would be to standardise fatigue reporting. From this foundation, a number of improvements can be made. For example, recording in a standardised format when a driver in a fatigue-related crash is accredited in a government scheme that permits more than "standard" hours of work.

The NTC has developed a list of priority fatigue issues, as well as data collection and research options. The framework aims to improve roadside enforcement data collection, improve and standardise crash investigation reporting and crash codes, and to undertake scientific research in partnership with the Alertness CRC.

Drawing on fatigue expert advice, Alertness CRC research activities and submissions to the NTC discussion paper (published for consultation on 21 August 2015) the presentation explains how the framework can measure and improve our understanding of fatigue impairment in a number of areas, including:

- frequency and impact of higher-risk driving schedules
- sleep quality and quantity of sleep in rest breaks
- impact of night driving
- health and well-being of heavy vehicle drivers.

The presentation concludes an appraisal of some risks and challenges associated with data collection and fatigue research.

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Extended Abstract

Since the introduction of heavy vehicle model laws in Australia in 2008, a number of measures, including a general duty not to drive while impaired by fatigue and Chain of Responsibility obligations on third parties, have contributed to a reduction in crashes involving heavy vehicles. However, crash statistics and driver attitudinal surveys indicate that driver fatigue remains a significant contributor to the road toll.

Drivers of vehicles over 12 tonnes (or buses over 4.5 tonnes with capacity to carry 12 or more people) are regulated by the Heavy Vehicle National Law (HVNL) in all Australian jurisdictions except Western Australia and the Northern Territory. The HVNL is administered by the National Heavy Vehicle Regulator (NHVR). This is a significant national law reform, not only enabling a single rule book across jurisdictions, but providing a framework to standardise data collection, for both enforcement and research purposes.

The HVNL has five key tools to reduce driver fatigue:

1. Duty of driver to avoid driving while fatigued
2. Duty of third parties to ensure business practices will not cause driver to be fatigued
3. Advanced Fatigue Management (AFM) within a safety management system approach
4. Maximum work and minimum rest rules: up to 12 hours work in 24 hours for drivers on standard hours, and 14 hours in 24 under Basic Fatigue Management (BFM)
5. Work diary record keeping.

These are supported by work safety principles, operational practices and industry schemes.

Heavy vehicle driver fatigue is a complex policy area and the impact of these regulations on driver fatigue is not definitive, particularly the effectiveness of the work and rest rules. There is also an opportunity to standardise how data is collected through enforcement activities, crash investigations and surveys.

Without improvements to data collection, supported by robust and validated research, the underpinning evidence is not available to support further fatigue reforms. For this reason, in November 2014 the Transport and Infrastructure Council, an organ of COAG, endorsed the NTC and NHVR to develop within two years a national framework to collect real-life operational data to better inform broader fatigue policy directions in the future.

In early 2015, the NTC surveyed road agencies, police and industry to benchmark current data collection processes and to capture preliminary fatigue issues that could be addressed in the framework. In August 2015, the NTC released the *Heavy Vehicle National Fatigue Data Framework discussion paper* for consultation. This paper identifies and prioritises regulatory fatigue issues, sets out framework principles, and proposes data collection and research activities. This includes consideration of new heavy vehicle crash investigation processes.

The NTC will make recommendations to the Transport and Infrastructure Council in 2016.

Road agency and police perspective

Governments support development of a data framework. Three significant issues were raised:

1. ***Length of the major rest break.*** A driver on standard hours must have a seven hour major rest break in a period of 24 hours. Fatigue research recommends that between 5-8 hours of sleep is required per night, depending on individual biology. Better data is sought to measure sleep quality and quantity in major rest breaks and to assess whether there is sufficient sleep opportunity in a major rest break of seven hours.
2. ***Additional hours of work under BFM.*** Better data is sought to assess whether the additional two hours a BFM driver can work is sufficiently off-set with current counter measures (including reduced night shifts). An assessment of the counter-measures could also be linked to a validation of the AFM risk classification system.
3. ***Nose-to-tail schedules***. Under the current counting rules that determine when a 24 hour period commences, data is sought to measure the fatigue impact from allowing two long periods of work in a 24-hour period (separated by a major rest break).

Industry perspective

In early 2015, the NTC developed multiple-choice and free-text survey questions with input from the Australian Trucking Association (ATA) and NatRoad. The survey was hosted on survey monkey and made available on the NTC website. The survey was also promoted by the ATA and NatRoad. The survey established a baseline of what fatigue, crash and incident data operators collect and what operators do to assess fitness to work. The survey also identified fatigue issues and options from an industry perspective.

There were 107 respondents. Over half the respondents were operators, a quarter were drivers and less than ten were trade associations. One respondent was a freight customer. The results can only be considered indicative of industry views.

Respondents largely welcomed higher-quality data on crash incidents and near misses. A challenge identified was operator reliance on manual systems, driver interviews and observational information to assess driver fatigue. Only around a fifth of respondents reported using outward and inward-facing camera and other technologies to.

Highly-rated factors contributing to fatigue from industry perspective was poor fitness for work, especially pre-trip fatigue caused by insufficient sleep and rest during a long rest break. Other contributing factors rated highly by respondents included the availability and quality of rest stop areas and the quality of sleep obtained on a driver’s rest break. Around a third of respondents also regarded a driver’s work schedule as a fatigue risk factor. Less than a fifth of respondents identified the length of the driver’s rest break as an issue.

The importance of delays at distribution centres was raised as a factor that should be assessed for correlation with crashes and near misses. Another issue cited was the complexity of the fatigue laws which makes it more challenging to manage fatigue.

Fatigue expert advice

In March 2015, the NTC commissioned expert advice on the development of the data framework from the Centre for Accident Research and Road Safety, Queensland University of Technology, the Transport and Road Safety Research unit at the University of New South Wales, the Institute for Breathing and Sleep at Austin Hospital and the Appleton Institute, Central Queensland University.

Expert advice recognised fatigue risks with insufficient rest opportunities in the regulations, night driving (especially work periods that end between midnight and 6am), length of work opportunities and threshold issues relating to the exclusion of local work. Identifying whether there were adequate counter-measures in place to offset additional work permitted under BFM and AFM was also a significant issue.

In relation to the development of a data framework, experts advised that the framework needs to have clearly articulated high-level goals and specific objectives, with clear implementation path to realisation. The data framework should be organised around collection of scientific evidence based on an agreed scale of fatigue impairment.

Proposed framework activities

Standardised crash investigation and reporting processes. Understanding the fatigue impact of HVNL regulations can be improved by standardising how fatigue impairment is identified and reported across Australian jurisdictions. There are three potential focus areas:

1. Standardised improvements to how crash investigators identify and categorise fatigue and alertness impairment as contributing factors, including the application of 'fatigue likelihood' and 'fatigue impact' scales. This would replace current *yes/no* fatigue reporting.

2. Standardised improvements to what data crash investigators collect from heavy vehicle drivers where fatigue had a likely impact. Current thinking in road agencies is that the following three questions standardised and collected are most critical:

1	Was the driver on standard hours, BFM or AFM?	____standard/BFM/AFM
2	When did the driver wake up from the last sleep?	____time since wake up
3	How much sleep did the driver have in the last 24/48 hours?	____hours

3. Review the Australian Transport Safety Bureau operational definition of relative fatigue.

Collection and analysis of work diary records based on activities identified during compliance and enforcement activities. Police and road agencies interact with heavy vehicle drivers through compliance and enforcement activities. These interactions provide an opportunity to collect improved fatigue data. Under this proposal, national processes are developed to collect and transmit 28 days of de-identified work diary records when a practice of concern is identified during enforcement activities. For example, the identification of nose-to-tail schedules. The collection of 28 days of work records allows fatigue experts to assess the risk in the context of a working week, and the frequency of practices within a 28 day period.

New research to measure the impact of specific regulations. There are four research areas where the Alertness CRC has expertise to provide comparative data on the impact of specific regulations:

- field studies using alertness monitoring devices to scientifically compare fatigue and alertness impact of different schedules (e.g. a comparative analysis of nose-to-tail and conventional shifts; and standard hours compared to BFM)
- objective monitoring of sleep during rest periods, to assess the level of sleep drivers are achieving during short and major rest breaks
- data fusion and data modelling undertaken by the Alertness CRC – utilising multiple sources of scheduling and crash data to improve understanding of linkages between different regulatory provisions and alertness levels
- develop and test practical and validated methods to screen and manage sleep disorders amongst heavy vehicle drivers.

Periodic industry surveys to collect large-scale attitudinal and behavioural data regarding driver and operations' management of fatigue and alertness. Use surveys to quantify the range of operating schedules and practices across the industry so that baseline risk levels can be established.

Alertness CRC

The data framework will be supported by the Alertness Safety and Productivity Cooperative Research Centre (Alertness CRC), a consortium of industry, academics and technology developers. The Alertness CRC aims to develop predictive tools to reduce occupational fatigue, and improve alertness, safety and productivity.

The data framework will integrate Alertness CRC research to measure the impact of fatigue regulations.

The longer-term challenge is to develop a simple, repeatable indicator of when a person is too tired to drive safety that can be applied in the workplace or at the roadside. If this can be achieved, the NTC can work with industry and the community to develop a straightforward performance-based law that is simple enough to be easily understood by those who need to comply with the law and those who enforce the law.

Safe System Roads for Local Government

Aaron, Campion[a], David McTiernan[b]

[a] GHD NZ Limited, [b] ARRB Group Limited

Abstract

The Safe System approach to road safety has been in place in Australasia for over a decade, but understanding and application by local road practitioners remains limited. The Austroads project *Safe System Roads for Local Government* (ST1769) is seeking to develop guidance for local government practitioners on how to assess sites of concern and identify how they can be best treated using the principles of the Safe System approach. The project is ongoing but nearing completion; this paper provides an overview of the approach developed from this project.

Through crash data analysis and consultation with the project working group of Australian jurisdictions and the NZ Road Controlling Authorities forum, this paper discusses the significance of local government roads and their contribution to road trauma in both countries. It provides an understanding of the challenges faced by local government to address safety on local roads, discussing the funding challenges, network responsibilities and sets out key focus areas for high severity crashes in a range of relevant environments.

This paper highlights practical tools that have or are being developed, including the benefits of using GIS spatial analysis, mapping network risk based on iRAP risk measures to optimise safety efforts, giving an understanding of network risk, identifying high priority sites and achieving effective prioritisation.

Finally, using a case study example, the paper outlines the Safe System assessment method intended to be available to local government practitioners, detailing example interventions, their relevant application and Safe System focus.

The guide specifically looks to provide a practical, cost effective toolkit of interventions that will assist Local Government to move towards providing a safe system on their road networks.

The Project

Safe System Roads for Local Government is an Austroads project (ST1769) which seeks to identify and investigate cost effective measures and innovative treatments that improve road safety on locally controlled roads. The goal of ST1769 is to assist local government in Australia and New Zealand to implement road safety measures that will allow them to work towards achieving a Safe System on their local road network.

ST1769 seeks to deliver a Safe System approach through a practitioner's guide for local government, that is practical, readily accessible, affordable (low cost) and entirely relevant for local roads.

It is envisaged that this guide will form part of a practitioner's existing toolkit and support a council's overall safety management system.

The practitioner's guide will provide a structured method for assessing road safety hazards and risk at a project site, identify potential treatment options and evaluate the effect of these potential options.

The Safe System Approach

The Safe System approach is a guiding philosophy that is adopted by leading road safety nations. It is a foundation for road safety strategies and action plans adopted in both Australia and New Zealand.

The Safe System approach operates on the principle that it is not acceptable for a road user to be killed or seriously injured if they make a mistake and its success is measured in these terms. The approach aims to create a forgiving road system based on the following four principles (New Zealand Transport Agency 2014):

1. People make mistakes – People make mistakes and some crashes are inevitable.

2. People are vulnerable – Our bodies have a limited ability to withstand crash forces without being killed or seriously injured.

3. We need to share responsibility – System designers and people who use the roads must share responsibility for creating a road system where crash forces do not result in death or serious injury.

4. We need to strengthen all parts of the road transport system – We need to improve the safety of all parts of the system, roads and roadsides, speeds, vehicles, and road use so that if one part fails, other parts will still protect the people involved.

The Safe System approach in Australia and New Zealand has four pillars where action can be taken to fulfil the above principles. There are a number of conceptual representations of the Safe System approach available; the framework below illustrates the connection between the adopted vision, the pillars and the underlying principles in the Australian and New Zealand strategies.

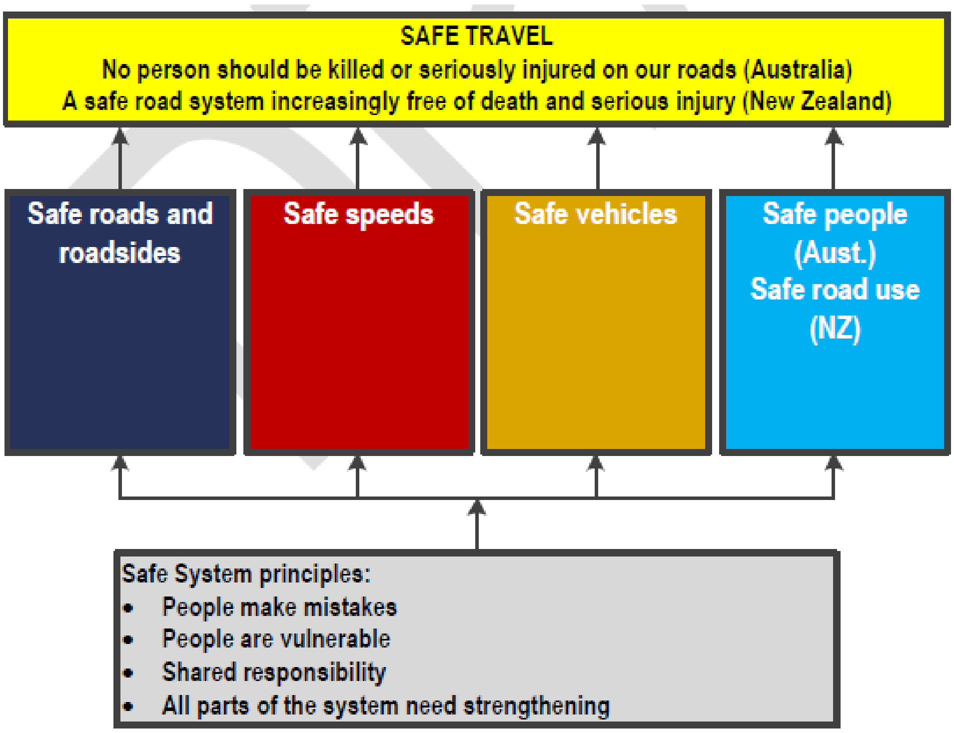

Figure 1. Safe System Approach Framework (Source ARRB Group)

The Safe System approach to road safety aims to eliminate fatal and serious road injuries (FSI). Key strategies for achieving Safe System objectives that are readily available to local governments are through road network improvements. These most directly relate to the Safe roads and roadsides and Safe Speeds pillars.

However, ST1769 aims to assist local government to move towards the Safe System approach by taking a much broader and integrated view of road safety and managing risk by identifying actions in all four pillars.

Why Focus on Local Roads?

The Austroads project *Road Safety on Local Government Roads* (Austroads 2010), investigated local government road safety, focussing on Australian and New Zealand roads. The analysis undertaken for that project established that the local government road network is vast, with local government managing approximately 82% of the public road network in Australia, and 88% in New Zealand.

Although the length of the local road network is significant, Austroads (2010) indicates that local roads carry considerably lower amounts of traffic than the state road networks. It is estimated that over 70% of the Australian road network serves less than 10% of the vehicle kilometres travelled (vkt), or conversely over 90% of the travel occurs on less than 30% of the network length. A similar situation is experienced in NZ with over 50% of the vkt occurring on the SH network, being only 11-12% of the total network length.

Austroads (2010) goes on to conclude that:

> *'In Australia, around half of all casualty crashes, and around 40% of all fatal crashes occur on roads managed by local authorities. The figures are higher in New Zealand (65% of casualty crashes and 46% of fatal crashes). Given the volumes of traffic using these roads, the risk to a driver of being involved in a casualty crash is higher on local government roads (between 1.5 and 2 times) than on state roads, and for some specific road types is likely to be substantially higher.'*

It is the responsibility of local government in both countries to manage road safety on their networks, and it is vital that local government contribute to the delivery of national and jurisdictional road safety outcomes on their networks if stated targets are to be achieved. It is therefore important that local government is supported in this endeavour through not just funding but, importantly, guidance and appropriate tools.

Challenges

Given the vast networks and low traffic volumes it is often challenging for local authorities to firstly understand where the greatest risks are on their networks and then how to best spend their limited investment dollars to achieve the greatest gains in road safety.

This can be compounded for local authorities with smaller populations dispersed over large lengths of road network, often resulting in limited funds to manage the safety and upkeep of the network.

In these circumstances, local government may not be able to deliver best practice, Safe System solutions; however they may well be better placed to make incremental improvements towards achieving a Safe System.

For ST179, the key question to be resolved was how then, can local government practitioners seek to deliver incremental Safe System road safety outcomes on their road networks?

Key Crash Types on Local Roads

The crash analysis undertaken as part of ST1769 evaluated the total number of injury crashes associated with each crash type and the percentage of crashes resulting in FSI outcomes for each crash type.

Admittedly this is a high level assessment with regional and local variances anticipated, however from this analysis the key crash trends presented for both urban and rural environments, for each country, are as follows;

Table 1. Primary crash types contributing to fatal and serious injuries on local roads.

Urban		**Rural**	
Australia	**New Zealand**	**Australia**	**New Zealand**
Pedestrian	Pedestrian	Pedestrian	Pedestrian
Off path on straight	Off path on straight	Opposing direction	Opposing direction
Overtaking	Overtaking	Overtaking	Overtaking
Off path on bend	Off path on bend	Intersection	Intersection
		Off path on straight	Manoeuvring

Understanding the key crash types commonly occurring on local roads permitted a targeting of local road locations and road environments and the shortlisting of potential treatment options for the case study guidance.

Identifying Risk Locations on Local Roads

ST1769 does not provide guidance on identifying or managing network risk; given the challenges identified, it is recognised that authorities will need to put systems in place for managing this and targeting locations of higher risk FSI crashes. This risk management approach will form an essential part of achieving a safe road system, and will greatly assist local government to get the best (safety) returns on their investment.

In terms of assessing and identifying network level risk, there are a number of tools available or under development. One example, developed by GHD, is the Safety Management App.

The Safety Management App assesses safety performance measures and enables local authorities to lead with risk based decision making, fundamentally critical for responsible and efficient network safety management.

In terms of determining the exposure risk with regards to safety, this is traditionally developed at an individual site level but ultimately the overall risk should be managed at a network level. In order to do this effectively GHD have devised their own (mostly automated) process to generate Risk Maps to capture the combined risk arising from the interaction of road users, vehicles and the road environment. The maps provide an objective view of where people are being killed or seriously injured and where their crash risk is greatest. GHD's web based spatial analysis evaluates the intersection type, speed environment, traffic volume and collision type at a site level and then calculates the crash density and the crash rate of each site. This is performed for both intersections and road lengths separately and generally follows the methods adopted by the International Road Assessment Programme (iRAP).

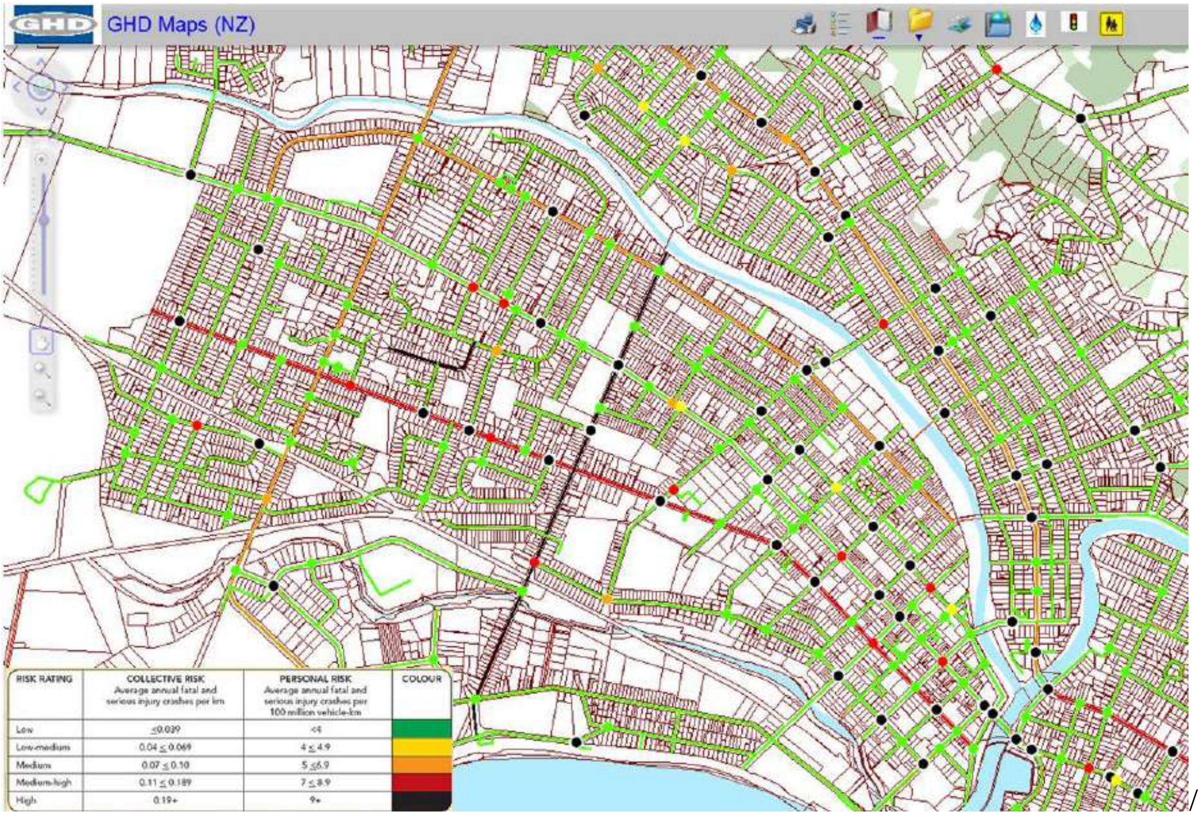

Figure 2. GHD's Geospatial Safety Risk Maps

We comment on the relevance of this type of spatial / network tool, given the earlier relationships established between network length, vkt, cash densities and the corresponding challenges many local authorities have in identifying and managing safety on their respective networks. The benefits of employing systems like this are;

- Ability to evaluate and visualise safety risk at a network level
- Provide a spatial representation of the safety levels on the network and indicate areas of high, medium and low concern.
- Establishing either local risk thresholds or align with national safety standards
- Enabling the authority, stakeholders, customers etc. to understand isolated risk in context of the network, which serves improved communication, planning and prioritisation of safety programmes.
- Identify sites of interest to advance for treatment investigation.

This is an initial process used in safety management, effectively screening the network to establish sites of concern. Once established, more detailed investigations and treatment options can be considered. It is here that the guidance developed by the Austroads project, are applied by practitioners.

Developing a Safe System Hierarchy of Control – Site Risk Assessment

ST1769 is a multi-staged project that is ultimately seeking to develop practitioner guidance for assessing the road safety problems at sites on local roads in a Safe System context. The guidance and assessment tools proposed will include:

- A review of Austroads Guides to provide greater direct relevance and guidance in local government-related issues.

- A new technical guide/report presenting case study applications of Safe System assessments for local roads

- Expansion/updating of the Austroads Road Safety Engineering Toolkit, which is a free on-line reference tool created for road infrastructure and safety practitioners, to incorporate Safe System risk assessments relevant to local government practitioners and case study treatments identified through this project (www.engtoolkit.com.au).

From the guidance and assessment tools to be developed, cost effective treatment options can be identified and selected that may be considered either best practice Safe System (primary) treatments or which may provide incremental safety improvements (secondary treatments) across each of the Safe System pillars.

Primary treatments are defined as best practice and satisfy the Safe System principles and have the potential to deliver zero FSI crashes. Supporting treatments are measures that provide incremental benefits towards achieving a Safe System. In both instances primary and secondary treatments may vary considerably in cost; typically primary treatments tend to be medium to high cost options, while supporting treatments tend to be regarded as lower cost, yet are considered to still be effective road safety treatment options.

Safe System Hierarchy of Control Case Study Example

The following simple example is provided to demonstrate the Safe System hierarchy of control assessment process being developed via ST1769.

The Site

The example case study site is a local road (Bay Street) passing through a busy shopping precinct. Bay Street has a number of low traffic side roads intersecting with it; Bay Street forms a left in/left out intersection which connects to a busy state road into the City CBD, see Figure 3.

Bay Street is a 50 km/h speed limited road and has a high local road traffic volume; it has a constant flow of pedestrians crossing traffic at a formal refuge island crossing, but also at other locations. There is a constant pedestrian flow crossing a side street (Grose Street), which is used by delivery vehicles and traffic as a short-cut to bypass the left out restriction with the state road.

The Safety Problem

There are concerns for the safety of pedestrians crossing Bay Street and Grose Street from through vehicle movements. Further, the pedestrian traffic interrupts traffic flow, creating uncertainty for drivers as some stop unexpectedly to wave pedestrian through while others do not.

There has been a series of vehicle-pedestrian collisions and near-misses and vehicle rear-end and t-bone type crashes.

Council has embraced the Safe System approach to guide action on its road network and is looking to identify the options available to improve pedestrian and vehicle safety along Bay Street.

A Safe System Hierarchy of Control Assessment

Several potential conflict points have been identified, which are indicated in red in Figure 3. Some conflicts may lead to more severe consequences than others, with the most significant being vehicles turning into Grose Street, impacting with a crossing pedestrian.

Figure 3. Example conflict diagram - Bay and Grose Street Intersection

With the use of the guide, a practitioner completes an assessment of safety issues using the Safe System hierarchy of control table as a framework to identify potential treatment options for each Safe System pillar and identifying if that option might eliminate, isolate, control etc. the risk/hazard.

This framework has been applied for the Bay Street case study example in Table 2. It should be noted that Table 2 presents an extract only of the range of potential conflicts and identified treatment options to provide an illustration of the approach. A more comprehensive assessment is presented in the project report that will form the practitioner guide.

It is not expected that treatment options will always be readily identified for every pillar, and it is acknowledged that not every option will eliminate the risk/hazard. It is important, however, that a broad view of the Safe System approach is adopted. The purpose of the framework is to switch on the thinking of the practitioner, to raise their appreciation to the potential that might be available, and to optimise Safe System performance which must include the Safe Vehicles pillar.

The most common view amongst practitioners, especially engineers, is that Safe Vehicles is not relevant to road practitioners – the traditional silo mentality sees that road managers in local government deal only with infrastructure and cannot apply vehicle based treatments. In ST1769, this view is seen as narrow and limiting the potential to address road safety with the full scope of primary and secondary Safe System solutions. Technology already exists that permits active communication between road infrastructure and vehicles and drivers; this begs the question of where does a treatment, which has a piece of road infrastructure directly informing an approaching vehicle to slow or stop due to a pedestrian crossing a road, fit within the Safe System pillars? Intelligent transport systems (ITS), intelligent speed adaptation (ISA), vehicle activated signs (VAS) and more break the traditional three E's view (Engineering, Education and Enforcement) of road safety – noting that each of these high-tech approaches rely on road infrastructure informing the road user (is that the driver or the vehicle?) – about what needs to occur to ensure a safe outcome.

While the application of high-tech options is currently limited to application along state road networks, there will be a point in the future when they become common place, affordable and readily applicable to local roads. The mindset of local government practitioners needs to be open to the opportunities now, so road safety can improve into the future.

Outputs

The outputs of the assessment process will be the identification of all the identifiable treatment options, with a description of the effectiveness to treat the particular hazard/risk (i.e. eliminate, substitute etc.). The treatment options will be associated with a Safe System pillar and how well it achieves the Safe System principles (i.e. primary or secondary treatment). Along with indicative costs, maintenance responsibilities and expected effectiveness of interventions, practitioners will have the necessary information to develop treatment interventions under a Safe System funding program, an area that state jurisdictions are moving towards as a means of meeting national road safety strategy objectives.

The Safe System hierarchy of control framework will also assist practitioners to communicate the effectiveness of treatment options to elected officials and the community; if an elimination of the problem is required, the framework indicates what is needed. With costs assigned, the elected and community representatives can more clearly understand the implication on budgets.

Conclusion

Based on the large vast networks, low traffic volumes, often dispersed crashes and limited funds, it was recognised that there are some very real challenges that often preclude local government from moving towards a Safe System on local roads.

It is noted that in situations of high crash density, it can be cost effective to implement a high cost solution and the appropriateness of the treatment will be dependent on the nature and scale of the crash patterns being addressed. However from overall cost, effectiveness, practicality and an ease of implementation viewpoint, supporting treatments, may be more accessible by local governments to achieve an overall incremental improvement on the network.

Whilst the practitioner case study guide that will be the final output of ST1769 is still in development (due for publication in 2016), the knowledge gained via the project thus far, including the site assessment framework, is considered to be of current value to local road authorities. The approach identifies key focus areas which are contributing to the FSI trauma incurred on these networks and it establishes a method for developing treatment responses.

In the meantime, it is recommended that practitioners continue to use existing methods such as risk maps and the Austroads Road Safety Engineering Toolkit to manage safety on the local road network.

Table 2. Safe System Hierarchy of controls

Control Method	Hazard /Crash Type	Safe Roads	Safe Speeds	Safe People	Safe Vehicles
Elimination Remove the hazard from the road environment	• Left Turn Vehicle – Pedestrian Conflict	• Ban Left turn • Ban Pedestrian Movement			• Pedestrian detection system
	• Right turn vehicle – pedestrian conflict	• Ban right turn • Ban pedestrian movement			•
	• Rear end collision	• Ban left turn			• City brake assist
Substitution Replace one hazard with another, less severe and more controllable	• Left Turn Vehicle – Pedestrian Conflict		• Create a shared zone with 30 km/h limit		• Bonnet designs
Engineering Controls – isolation Apply design modifications to minimise road user interaction with the hazard	• Left Turn Vehicle – Pedestrian Conflict	• Apply self-explaining road principles • Change kerb alignment to reduce turning speeds • Wombat Crossing • Street Scape modifications	• Physical changes to reduce vehicle speeds to less than 30 km/h		• Collision warning alerts
Admin. Controls Provide warning/advice to seek appropriate behaviour	• Left Turn Vehicle – Pedestrian Conflict	• Zebra crossings • ‘LOOK’ stencilling in path	• Create a shared zone with 30 km/h limit	• Education and awareness campaigns about right-of-way and yield laws	• Pedestrian Detection Systems
Personal Protective Equipment Use equipment					• Seatbelts, airbags • Bonnet design

to protect road users from FSI crashes					

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Local road mountable roundabouts – are there safety benefits?

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Abstract

Roundabouts are internationally accepted as being highly effective in improving safety at intersections. However, the installation of roundabouts at intersections is not always easy. Initiatives to improve safety at intersections include the use of mountable or mini-roundabouts on local roads. Similar in design to the traditional roundabouts, mini-roundabouts have the advantage of being more readily incorporated at restricted intersection geometries, the mountable central island allowing larger vehicles to mount the island to account for tight turning circles. Though not necessarily a new concept, little information is available on the design's efficacy. A case study of two such roundabouts suggests some safety benefits. When considering the overall kinetic energy at the subject sites, the levels of kinetic energy, in both vehicle and vulnerable road user-involved crashes, were far more favourable at the treated sites than those at the control site. A study using a larger dataset is recommended to validate results.

Background

Roundabouts are internationally accepted as being highly effective in improving safety at intersections. However, the installation of roundabouts at intersections is not always easy; the intersections often need to be widened to create the appropriate deflection and induce adequate reductions in approach speeds. Especially on local streets where intersection geometry is constrained by residential properties and budgets for improvement works are not large, traditional roundabout installation becomes problematic. An alternative option was needed.

Fully mountable "mini-roundabouts" have been in use in Melbourne in the recent past at local street intersections (AustRoads Ltd, 2013), as well as overseas, however, no evaluation of these has been completed, and little information exists on mini-roundabout effectiveness in general. Monash University Accident Research Centre (MUARC) was commissioned by the Transport Accident Commission (TAC) to complete a brief study to identify any quantifiable safety benefits associated with these roundabouts with respect to passenger vehicle and vulnerable road user, VRUs (pedestrian and cyclist) safety.

Mini-roundabout definition

Mini-roundabouts are essentially traditional roundabouts but with a smaller footprint and a traversable central island. The central island is adequately small in diameter such that the intersection does not require widening yet the island defines traffic movement at the intersection. Splitter islands are used to channel vehicles around the central island. Traffic operation at a mini-roundabout requires drivers to give way to vehicles circulating the central island (and vehicles approaching on the right in the event of potential conflict) and to travel around the island except where vehicle size impedes this (US Federal Highway Agency 2010, County Surveyors Society and Department for Transport, UK, 2011, Austroads, 2013). Typical defining features of a mini - roundabout include a traversable central island of diameter between 1 and 4 m, a dome of no more than 125 mm and a raised kerb of no more than 6 mm (AustRoads, 2013). The accompanying linemarking is typical of that at traditional roundabout designs.

Mini-roundabouts differ from traffic circles in two distinct ways – traffic circles at intersections operate as Give Way sign controlled intersections; and generally do not involve vehicle channelisation in to the circulatory roadway. That is, it appears to be used more as a traffic calming measure at the intersection than a traffic movement controlling measure. (County Surveyors, 2011)

Method

Two mini-roundabouts in line with the AustRoads prescribed definitions were identified as case studies to establish indicative effects of these treatments on intersection safety. A nearby local street intersection, governed by Give Way sign regulation, was identified as a control site. Key features of all three sites included 50 km/h posted speed limits, on-street parking and 2.5-3 metre traffic lanes. Vehicles along Road 1 of the control site were governed by a Give Way sign, vehicles in the east-west direction maintains right of way; vehicles along Road 1 and Road 2 of the treatment sites are governed by traditional roundabout rules. Covert measurements of the speeds of approaching vehicles were recorded over a two-day period via laser gun. Speed measurements were collected only for Road 1 of each treatment site and control site (the north-south direction). Speeds along Road 2 of the treatment sites (east-west direction) were assumed to have similar speeds to those on Road 1 of the treatment sites given similar design features. Speeds along Road 2 of the control site (east-west direction) were assumed to be at the speed limit, in this case at 50 km/h.

To evaluate the impact of the mini central island on mitigating impact angle, the incidence of drivers traversing the roundabout (thereby reducing the benefit of the presence of the island) was recorded and the worst case impact angle calculated of two vehicles colliding while circulating the central island. To do this, a DVD recorder was mounted on a pole at one of the treatment sites and footage recorded. Driver behaviour patterns and compliance to road design regulations at the intersection was noted. The island was marked in 200 mm increments and encroachment of the island was categorised in terms of full, semi and non-compliance. Encroachment was defined as follows: “compliant” defined as the encroachment of the island of less than 200 mm; “semi-compliant” 200 mm-1800 mm encroachment; “non-compliant” greater than 1800 mm encroachment. The worst-case impact angles were calculated for a typical collision at the intersections in question using CORELDRAW software and a scaled diagram of the intersection. Any changes to impact angles were included in to calculations of respective kinetic energy (KE) levels at the intersections and compared to potential KE at a ninety-degree collision to establish relative safety levels.

These results were analysed and compared to those at the selected control site. Approach speeds, departure speeds, speeds at the intersections (impact speed) were analysed using the IBM SPSS statistical package (Version 20.0). Independent t-tests were used to compare the speeds at the intervention sites to the speeds at the control site.

Results

Mean Speed

The analysis consisted of 533 vehicles. In the interest of maintaining required paper length, only the mean impact speeds are reported, although approach and departure speeds were also collected. The mean impact speed at sites 1 and 2 were 23.78 km/h and 22.17 km/h respectively. Given there were no differentiating features on the intersecting road of each treated intersection (east-west direction), the same mean speeds were assumed for Road 2 of each treated site. The mean impact speed measured at the control site was 12.61 km/h. Given drivers had right of way on the intersecting road of the control site (Road 2), it was assumed that mean travel speed would be at the speed limit of 50 km/h.

Overall speed environmental at intersections

While results indicate higher mean speeds on Road 1 of the treatment sites compared to the control site, when mean speeds on Road 1 and Road 2 were averaged, average speeds were found to be lower at the treatment site than at the control site. At treatment sites 1 and 2, taking mean impact speeds to be equal along either road, average speeds were 23.78 km/h and 22.17 km/h respectively. At the control site, taking speeds along the road with right of way to be at the speed limit (50 km/h), average speed was found to be 31.3 km/h. Taking a mass of 1 tonne, overall KE at the treatment sites were calculated to be lower than those at the control site.

Impact Angle and Compliance

Scaled drawings of the mini-roundabout on site indicate a reduced impact angle of approximately 15 degrees as a result of the mini central island. This can lead to a reduction in overall KE of around 13% (Table 1). However, video footage of the subject sites suggests compliance to the central island during peak periods was low. Nearly all vehicles encroached the central island to some extent. In the AM period, encroachment was typically greater than 1800 mm, drivers being non-compliant to the presence of the island. In the PM period where perhaps time pressure was not a prominent factor, encroachment was typically a third, or drivers can be considered semi-compliant to the island.

Table 1: Summary of key results

	Mean Impact Speed (km/h)	Std Dev	Average Impact Speed across both roads (km/h)	Av KE across both road (kJ)	AV KE across both road incorporating Impact Angles (kJ)	% reduction in av KE
Site 1 (n=272)	23.78	8.18	23.78	21.82	18.99	13%
Site 2 (n=230)	22.17	7.59	22.17	18.95	16.49	13%
Control (n=31)	12.61	6.41	31.31	37.81	37.81	0%

Discussion

Safety Implications for Drivers

Results of this preliminary study suggest some safety benefits in the use of mini-roundabouts on local roads. While this is not evident when comparing only the mean speeds along one road of each site, when considering the overall kinetic energy at the treated sites, the average levels of kinetic energy in vehicle involved crashes were far more favourable at the treated sites than those at the control site. Using the respective average velocities for each direction, and using a standard mass of vehicle (1 tonne), the average KE for the intersection was calculated. This indicated that average KE at the treated sites was approximately 20 kJ compared to 38 kJ at the control site. Based on studies on velocities relating to biomechanical tolerance for side impact crashes, (Tingvall and Haworth, 1999) limits of KE levels are around 97 kJ, (Candappa, Logan et al 2014) indicating that at the control site, the potential KE is well over third the tolerable levels while at the treatment sites, this is around a fifth (Figure 1). This indicates that considering the site as a whole, the KE generated by a typical crash at the control site is higher than that generated at either treated site. This suggests that in the event of a crash, sites with a mini-roundabout are likely to produce less severe injury outcomes than sites with a Give Way sign. The slightly reduced angles are also likely to contribute to reduced KE levels. While compliance to the central island appears to be an issue at the sites studied, this appears to be more a problem when only one vehicle is present at the intersection. Potential conflict could arise when a heavy vehicle unable to circulate the island and traverses over the island, conflicts with a passenger vehicle circulating the island. This is considered an infrequent occurrence however given these mini-roundabouts are intended for local roads where the incidence of heavy vehicles is restricted more to garbage trucks, ambulances and perhaps the occasional truck.

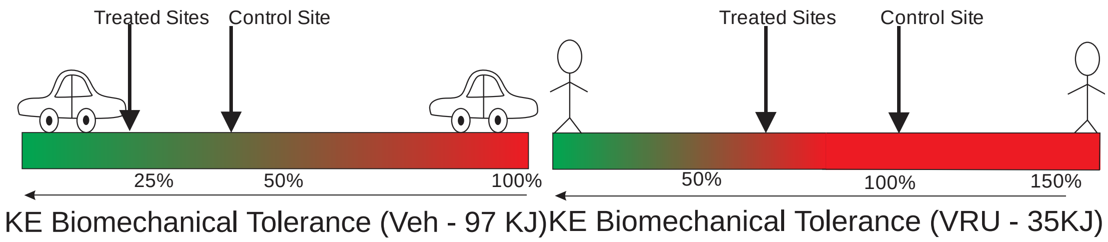

Figure 1 – relative KE levels for vehicle and vulnerable road user crashes

Safety benefits associated with the mini-roundabouts are generally in line with early UK studies that suggest reductions in crashes at mini-roundabouts, and an FHWA study that found mini-roundabouts to provide similar benefits to traditional roundabouts (AustRoads, 2013). Brillon (2011) also found a decrease in crashes in Germany (30%) when converting from cross intersections to mini-roundabouts. Another US study however, found there to be no change in crash numbers after mini-roundabout installation (Waddell and Albertson, 2005 cited in Austroads, 2013).

Safety Implications for Pedestrians and Cyclists

Safety benefits are also associated with mini-roundabouts when considering collisions involving pedestrians and cyclists. At the treated sites, KE levels were around 20 KJ, around 60 % of what is regarded as the maximum tolerable KE levels for vulnerable road users. (Tingvall and Haworth, 1999) At the control site, KE can be around 40 kJ, over the survivable levels. Impact angles are not expected to greatly affect these KE levels, though the specific point of contact with the vehicle can sometimes exacerbate outcomes. This increase in safety levels for vulnerable road users is in line with some overseas study findings that suggest mini-roundabouts can improve safety for vulnerable road users, while other studies report higher injury crash reductions for pedestrians and cyclists.

Future research

A study using a larger database is recommended to further validate these findings. Some safety benefits were apparent through the use of mini-roundabouts, particularly in the form of speed reduction. However, the mean speeds were found to be higher at the mini-roundabout than at the Give Way control site. This could suggest a greater speed reduction is effected by Give Way signs than a mini central island. In order to achieve the goal of safer local intersections, it is worth investigating further whether the US practice of All-Way Stop signs on local streets produce similar lowered speeds through intersections, producing similar or greater safety benefits at lower costs.

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Perceptions of the prevalence of self-organising amongst Australian road safety stakeholders: a comparative perspective

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Abstract

The Australian road traffic fatality rate is slowing down at a much lower rate than that of comparable high income countries. This slow rate of reduction may be attributable to a wide range of causes such as deficits in coordination and low community engagement. However, it may also be due to the absence of understanding of systems thinking in road safety in Australia. This exploratory study aimed to investigate the perceptions of Australian stakeholders about the prevalence of a principle of the Dynamic Systems Theory, namely: self-organising. The results pointed to a need to decentralize the road traffic injury prevention efforts in Australia through a range of self-organising principles and the adoption of emergent rather than deliberate strategies.

Introduction

The challenge in Australia road safety management is not its ability to head towards zero (see Corben *et al.*, 2010; Gargett *et al*, 2011). The downward trajectory of fatality rates over the last forty-five years across all jurisdictions shows that Australia is heading closer to zero from a high of 30.4 road traffic fatalities per 100,000 in 1970 (OECD and ITF, 2013). Take the State of Western Australia, for instance. It has reduced its road toll in the last four decades by four-fold through the simultaneous deployment of evidence-based road safety measures and centralisation of effort (Dieter, 2011). Likewise, the Australian Capital Territory's fatality rate, at 3.40 (Australian Bureau of Statistics, 2010) is much closer to zero than any other jurisdiction. However, the challenge in Australia road safety management is the need to accelerate the rate of reduction of road traffic fatalities (Gargett *et al*, 2011). In fact, unless the rate of road traffic fatality reduction is accelerated in Australia, simple calculation shows that its largest State (Western Australia) will need (all things being equal) another 80 years to achieve a fatality rate of 0.52 per 100,000 population**.**

To avert this slow progress pattern and in some jurisdictions reverse the trend (McIntosh, 2013), Gargett *et al*. have called for trend breaking change (2011). Likewise, Dieter (2011) has proposed the notion of co-development of strategies and policies with enhanced levels of community engagement. Similarly, Johnston (2010) has called for a constituency for safety. Furthermore, May *et al* (2008) have attributed the slow rate of reduction to the "culture of speed" in Australia. Most importantly, citing Dekker (2011) in a comparison of system models, Salmon *et al*. have concluded that in terms of systems thinking, Australian road safety strategies tend to "… go 'down and in' rather than 'up and out' to understand and rectify road traffic crashes" (2012, p. 1834). The 'up' in this case represents "…Government, road authorities, road designers, societal norms, road design, road rules etc." (Salmon *et al*., 2012, p. 1834). The 'out' signifies a concern for factors other than 'frontline behaviour' or road users (Salmon *et al*., 2012, p. 1834). In the same vein, May *et al.* (2008) have observed the fact that " … Australian public policy on road safety management remains constrained in its thinking, focusing on technical or engineering solutions or on narrow approaches to changing driver behaviour" (p. 395). Moreover, others have recommended a redesign of the Australian transport safety system (May *et al*., 2011). This redesign is said to be achieved through holistic thinking (May *et al.* 2008).

Despite various attempts to hypothesise as to what may arrest the current rate reduction trend in Australia, little research has been conducted into the nature of the Australian adoption of a systems approach. Indeed, "… modern strategies do not include essential aspects of systems theory that describe relationships and interdependencies between key components." (Hughes *et al.*, 2015, p. 271). In fact, it is not known how Australia fares against other comparable countries in terms of the adoption of theories which contribute to a dynamic, resilient and flexible system. One such theory is Dynamic Systems Theory, which explains how self-organised systems build flexibility, resilience and dynamism. The origins of self-organisation, although varied, have been traced to two features of systems capable of engendering emergent order in Dynamic Systems Theory.

Dynamic Systems Theory: Self-Organising

Self–organisation is made possible by experiential learning-oriented cultures (Zohar and Borkman, 1997). In these cultures, which thrive on knowledge, an executive consciousness is developed (Kayes and Kolb, 2005). This high level of team development represents collective growth (Knapp, 2010). Self-organising can be satisfactorily explained through five dynamic systems principles, namely: *circular causality*, *continuity*, *empowerment*, *self-augmenting* and *self-maintaining*.

The emergence of orderliness (in this case the reduced likelihood of road traffic crashes) can occur as a result of a combination of *self-augmenting* (positive) and *self-maintaining* (negative) feedback processes (Lewis, 2005). Positive feedback, or self-augmenting, is the vehicle for the emergence of new forms or behaviours, as new elements in the system are mobilized causing amplification of change (Lewis, 2005). Essentially, in a society where very few self-organizing institutions exist, change may remain localized. Negative feedback, on the other hand, or self–maintaining, restores orderliness as individual elements relinquish independence and embed into the system (Lewis, 2005). Self-maintaining is typical of inter-agency work patterns in emergencies, when a central, lead agency takes over whilst others surrender some of their powers. In essence, a system self-maintains when it centralizes under stress or as a contingency. In the Australian State of Western Australia, for instance, the adoption of self-maintaining was evident in the coordinating function attributed to the former Office of Road Safety (Dieter, 2011).

Continuity represents a system's ability to flexibly respond to stress with a repertoire of responses. This ability to bounce back emerges from the interaction of a system's underlying components (Rvachew and Bernhardt, 2010). In this sense, the simultaneous deployment of road safety interventions at various levels of society aids the maintenance of continuity.

Circular causality, as opposed to linear causality, identifies two parts of a system, which repeatedly impact upon each other, namely: a higher-order part (structures, hierarchies) and a lower-order part (processes, constituencies). A change in the higher order function alters the manner in which the lower-order parts of the same system function. In turn, this change in the lower-order interaction patterns gives rise to modifications in the way the higher–order functions (Lewis, 2005). This mutual dependency of cause (e.g. changes in the local processes) and effect (e.g. alterations in the global structure) diminishes the influence of the environment on a system's direction (Küppers, 1999), rendering it resilient.

The sustainability of self-organising requires *empowerment* (delegation of power) (Laihonen, 2006). *Empowerment* can be achieved through a stage-approach which aims at equipping a team with the skills to self-organise.

Whilst these principles of self-organising are often employed in the design of dynamic systems, they have not been investigated in a context of road transport systems (Young and Salmon, 2015). Accordingly, it is pertinent to address the following research questions: a) which principles of self-organising are more frequently perceived as prevalent in the Australian road safety context?; and b) how does this Australian perception contrast with the perceptions of other comparable stakeholders?

Methods

Instrument Design

From the literature on Dynamic Systems Theory and its principle of self-organising, eleven statements were designed into an online, self-administered survey (Table 1). The statements in Table 1 were rated along a 7-point Likert scale from Always to Rarely.

Table 1: Description of Survey Variables

DST Concept	Proponent	Variable	Survey Statement
Experiential Learning	Zohar and Borkman, 1997	*Learning*	My community (i.e. clubs, schools, ethnic groups etc; not family or friends only) thrives in experiential learning, where its members are constantly looking for opportunities to learn from experience at a local level.
Executive Consciousness	Kayes and Kolb, 2005	*Advocacy*	My community has developed strong constituency (advocacy) for road safety issues at a local level
		Cohesion	My community is highly cohesive, with groups organizing around social issues at a local level.
		Interest Groups	There are a lot of interest groups in my community at a local level.
Voluntary Activities	Bacharach and Lawler, 1980	*Volunteering*	My community organises voluntary activities on a regular basis at a local level.
Self-Augmenting	Lewis, 2005	*Word Spread1*	My community is quick to spread the word about crash statistics.
		Word Spread2	When there are changes to the law or road rules, my community spreads the word very quickly about the changes.
Self-Maintaining		*Central Command*	If there is an emergency, there is a central command (either of local groups or local authorities) that is immediately formed at a local level.
Empowerment	Hut and Molleman, 1998	*Empowerment*	The local council may delegate the authority to organize behavior changing campaigns to road safety community groups at a local level.
Circular Causality	Googins and Rochlin, 2000	*Circular Causality*	If funding allocation is changed, the local Council interaction with community-based interest groups is altered with Council taking on the role of conducting behavior changing programs.
Continuity	Lewis, 2005	*Simultaneous*	In my country, road safety interventions (i.e. programs to reduce road traffic fatalities) are deployed at various levels (government, community, private sector etc.) simultaneously.

Sampling Techniques

Stratified sampling techniques were adopted in this study to identify the survey takers, including initial website search and snowballing to form a sampling frame, from which respondents were randomly selected. The inclusion criteria included job role related to road safety and familiarization with the coordination of road safety at a local level. In total, 558 e-mail invitations (with a link to the survey) were sent out to all the members of the sampling frame. Seventy-six (13.6%) respondents completed the survey. Of these, nearly half (48.7%) were Australians (Table 2). Canadians represented the second largest group at 15.8 per cent.

Table 2: Sample Characteristics

Country of Residence	*N*	%
Australia	37	48.7
Brazil	1	1.3
Bulgaria	1	1.3
Canada	12	15.8
Colombia	1	1.3
Finland	3	3.9
Ireland	1	1.3
Kenya	1	1.3
Malaysia	1	1.3
Netherlands	1	1.3
New Zealand	3	3.9
Sweden	2	2.6
Uganda	1	1.3
UK	5	6.6
Uruguay	1	1.3
USA	2	2.6
Zambia	2	2.6
Zimbabwe	1	1.3
Total	76	100.0

The *Global Status Report on Road Safety 2013* (WHO, 2013) was used to group respondents other than Australians under three income levels – high, middle and low. Due to the low numbers for the last two income levels, the analyses will focus predominately on high income countries as these compare to Australia.

Data Analysis

Cross-tabulation examinations were conducted to investigate the perceived prevalence of self-organising across the three country income levels. Significance testing employed Fisher's Exact Tests with a significance level of .05.

Results

This paper aimed to address two research questions. Firstly, it sought to identify the principles of self-organising perceived by Australian stakeholders to be prevalent in the Australian road transport system. In this respect, not one principle was thought to always be present (Table 3). *Continuity* (i.e. simultaneous deployment of road safety interventions at all levels) was most commonly selected as "Always" present, by nearly a quarter (24.3%) of the Australian survey takers. Furthermore, four principles were viewed as "Often" existing in Australian responses to road traffic crashes, namely: *experiential learning* (24.3%); *executive consciousness through advocacy* (21.6%); *executive consciousness through interest groups* (24.3%) and *self-maintaining through central command* (27%). In the case of the latter principle (self-maintaining through central command), almost half of the respondents (21.6% + 27.0%) perceived of it as existing with some frequency in Australian responses to road traffic crashes. However, two principles of self-organising did not seem to be perceived as being frequently observed in Australian responses to road traffic crashes. These were self-augmenting through the spread of a central message and empowerment through delegation (Table 3).

Table 3: Prevalence of the principles of self-organising

	Percent selecting frequency of perceived prevalence			
Variable (number of valid responses)	**Always**	**Often**	**Sometimes**	**Rarely**
Learning (N=25)	5.4	24.3	24.3	13.5
Advocacy (N=20)	10.8	21.6	16.2	5.4
Cohesion (N=17)	2.7	16.2	16.2	10.8
Interest Groups (N=21)	10.8	24.3	13.5	8.1
Word Spread1 (N=23)	2.7	18.9	18.9	21.6
Word Spread2 (N=24)	5.4	16.2	18.9	24.3
Central Command (N=26)	21.6	27.0	8.1	13.5
Empowerment (N=22)	5.4	18.9	8.1	27.0
Circular Causality (N=20)	2.7	13.5	21.6	16.2
Simultaneous (N=22)	24.3	16.2	10.8	8.1

Note: SPSS only outputs options selected by respondents (or options with values > 0). Frequency adverbs not selected by the respondents (or with values > 0) are not shown.

Secondly, this paper aimed to compare the perceptions of the Australian respondents to those of comparable stakeholders. In this regard, there were no significant differences (p <.05) between the Australian respondents and others on all but one principle of self-organising: only *self-maintaining through central command* (p = .02) appeared to set Australians apart. In this sense, Australian stakeholders were slightly more likely to perceive this principle to be “always” or “often” in evidence in the responses to road traffic crashes (Table 4) when compared to high income country respondents. Both Australian and high income country respondents seemed to perceive *self-maintaining through central command* far more often than middle and low income country survey takers, thus suggesting that this principle is typical of countries comparable to Australia.

Table 4: Central command (frequency)

	Country of residency				
	Australia	**High Income**	**Middle Income**	**Low Income**	**Total**
Always	8	7	0	0	15
Often	10	5	0	1	16
Sometimes	3	4	3	2	12
Rarely	5	1	3	0	9
Unknown	11	12	1	0	24
Total	37	29	7	3	76

When asked how fast the setup of central command occurred in emergencies related to road traffic crashes in their communities (Table 5), the respondents from high income countries were slightly more likely than the Australians to perceive this to occur quickly (p<.01). Australians were twice as likely as high income country respondents to view the speed of the establishment of central command in road traffic crashes as slow.

Table 5: Central command setup (speed of adoption)

	Country of residency				
	Australia	**High Income**	**Low Income**	**Middle Income**	**Total**
Quickly	21	23	1	1	46
Neither	9	4	1	1	15
Slowly	7	2	1	5	15
Total	37	29	3	7	76

Discussion

Significance

The results suggest that across the income divide for countries there are no significant statistical differences in the perceived application of Dynamic Systems Theory constructs except for *self-maintaining through centralisation of command*. In this sense, the Australian road transport system is perceived to self-maintain slightly more than other comparable high income countries such as Sweden, Canada, the UK, New Zealand, the Netherlands, Finland and Ireland. Given the State-based management of road safety in Australia, such centralisation presumably applies at State rather than national level. Importantly, the establishment of local level central command in Australia in response to a road traffic crash emergency does not seem to be perceived to be as quick as in other comparable countries.

It is equally apparent that the Australian respondents do not appear to perceive the Australian road transport system to self-augment or empower constituent system parts e.g. community groups. In this sense, it may be hypothesised that there might be little spread of a central message in road safety in Australia. The consequence of a lack of self-augmenting may include a reduced likelihood of the existence of public approval for system reforms, especially changes related to speed, alcohol, drugs and mobile telephone use (see Canoquena and King, under review). For this and other reasons such as high levels of distracted driving (Young and Salmon, 2015), the average car occupant fatalities (2007-2011) in Australia are amongst the highest in the OECD (OECD and ITF, 2013).

In essence, the road safety system in Australia appears to be too centralised, unlike other comparable countries. In the UK, for instance, innovative plans by associations such as TyreSafe typify executive consciousness of interest groups or communities of practice. Over holiday periods, TyreSafe, a knowledge-oriented institution reaches out to its members and issues warnings and advice. The emergent order constitutes the adherence by drivers to the counsel in the way of voluntary periodical checks of the air pressure and status of tyres.

The significance of these findings may be said to be twofold. Firstly, this new knowledge about the Australian road safety system has the potential to identify areas for improvement (Hughes *et al.*, 2015). For instance, it is known that continuity alone can be responsible for 20-30% fatality rate reduction (Corben *et al.*, 2010). In fact, Graham (2013) has attributed 50% of the reduction in the number of teenage drink-driving offences to a package of measures (i.e. continuity) in a country often compared to Australia - i.e. New Zealand. These interventions included regulatory changes, Police enforcement, mass media advertising, public attitude surveys and crash data reports (Graham, 2013). Nonetheless, less than half the respondents in this study perceived continuity to be prevalent in the Australian context. Therefore, due to the effectiveness rate attributed to continuity, it ought to feature more prominently in Australian road safety management.

Likewise, the fact that there is '… substantial rhetoric … about the desirability of active involvement of community members …' in traffic safety policy development (Howat *et al.*, 2001, p. 267), it is surprising that nearly a quarter of the Australian respondents perceived self-augmenting to rarely be prevalent. Elsewhere, self-augmenting has been widespread (see Appendix).

Secondly, the results in this study point to the slow uptake of self-maintaining in Australia when it is most required (i.e. coordination of emergencies). Whilst McIntosh (2013) and Deller (2010) have identified deficits in the coordination of effort to explain the slow update of coordinated responses (i.e. self-maintaining), the issue with Australia does not appear to be the mere existence of deficits in coordination per se as these are unlikely to impact directly on fatality rates. Other issues may be at play. For instance, the fact that States and Territories manage and are accountable for road safety in Australia (Job and Cook, 2012) should make self-maintaining more effective in Australia. However, this does not seem to be the case because it has not generated an emergent order. In other words, self-maintaining in Australia is not restoring orderliness. This might be explained by the fact that Australia is adopting *deliberate* (hence the delay in the adoption of self-maintaining) as opposed to *emergent* strategies (Mintzberg and Waters, 1985). In this sense, intentions or goals ought not to direct the course of action (Mintzberg and Waters, 1985). Rather, the interaction between the environment and the parts of a system shape the course of action (Mintzberg and Waters, 1985). This means working more from an emergent order perspective as opposed to deliberately planned strategies.

In essence, Australia will need to adopt self-augmenting strategies to spread scientific knowledge about contributing risk factors to road traffic crashes within the community and empowerment of community groups to redesign its cultural arrangements (May *et al*., 2008; Johnston, 2010).

Limitations

This study is not without limitations. The relevant sample was relatively small (37 for Australia and 29 for high income countries). Future research ought to broaden the comparison and engage a larger number of respondents from both Australia and a much wider range of OECD countries, especially high performers such as Iceland and Germany (OECD and ITF, 2013). This comparison is useful to help explain the existence of the wide gap amongst OECD countries in terms of road traffic fatality rates from a systems thinking perspective (OECD and ITF, 2013).

Most importantly, the missing values in the Australian responses limited the ability of the study to be definitive in its generalisations about the Australian stakeholders, thus the use of tentative language in the discussion and conclusion.

Conclusion

Australia appears to be centralising road traffic injury prevention more than it needs to. Whilst the centralisation of command through a lead agency is often called for by the WHO and the UN, adopting this inflexibly may not suit Australia as it wrestles with the need for grass-root cultural shifts to modify road user attitudes. In this sense, the Australian road transport system should be more flexible and dynamic so as to only quickly self-maintain when is required such as in road traffic crashes. When it does not need to self-maintain, it should self-augment and spread a core evidence-based message about injury prevention; empower community groups; and allow local level structures to impact on and shape the course of action. Essentially, Australia will be best served by viewing the road transport system as one component of a much broader, dynamic and unpredictable system in its pursuit to arrest the slow rate of reduction in road traffic fatalities through attitudinal changes.

Greater gains in road traffic injury reduction may arise from decentralised yet coordinated responses to road traffic risk factors. This decentralisation within a coordinated framework will be achieved through a systems theory such as Dynamic Systems Theory, which focuses on the interplay amongst the system components (Young and Salmon, 2015) and provides a holistic appraisal of the factors contributing to road traffic crashes (Scott-Parker *et al.*, 2015).

Future research into the road transport system in Australia from a systems perspective should seek to identify actual gains in the adoption of the principles of self-organising. In this respect, it is pertinent to investigate the magnitude of the impact of self-maintaining, self-augmenting, circular causality or empowerment upon a country's ability to reduce its death toll.

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Appendix: Institutions Contributing to Self-Augmenting in Road Safety outside Australia

- Royal Society for the Prevention of Accidents (UK)
- RoadPeace (UK)
- Community Road Safety Councils (UK)
- Associazione Italiana Familiari e Vittime della Strada (Italy)
- Association Nationale des Victimes de la Route (Luxembourg)
- Safe Kids (NZ)
- Congressional Caucus on Global Road Safety (USA)
- Mothers Against Drinking Driving (USA)
- National Society for Road Safety (Sweden)
- Institute for Road Safety Research (Netherlands)

Please note: abstract *only* available - check website for the full version of this paper

The Victorian Cycling Road Rules Review – recommendations for safer cycling

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Abstract

The Victorian Cycling Road Rules Review was completed in mid March 2015. The review incorporated a number of forms of investigation - a literature review, crash stats analysis, key informant interviews, a council survey and a road user survey.

This paper will provide an overview of the review. It will cover the methods used, the issues that emerged, and a discussion of the recommendations.

The Review identified certain road rules to be considered for possible amendment to improve bike rider safety, and also rules that required further communication and higher road user awareness to make them more effective and increase their use.

An outline of how the recommendations have been evaluated and progressed will be provided.

The National Road Safety Partnership Program providing a pathway for any business/organisation to create a positive road safety culture

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[a] ARRB Group, [b] Origin, [c]Centre for Accident Research & Road Safety – Queensland, [d]Toll NQX, [e]Uniting Care Queensland, [f]Zurich Insurance and [g]Viva Energy

Abstract

The National Road Safety Partnership Program (NRSPP) is an industry-led collaborative network which aims to support Australian businesses in developing a positive road safety culture. It aims to help businesses to protect their employees and the public, not only during work hours, but also when their staff are ‘off-duty’.

How do we engage and help an organisation minimise work-related vehicle crashes and their consequences both internally, and within the broader community?

The first step is helping an organisation to understand the true cost of its road incidents. Larger organisations often wear the costs without knowing the true impact to their bottom line. All they perceive is the change in insurance or vehicle repairs. Understanding the true cost should help mobilise a business’s leadership to do more. The next step is ensuring the business undertakes an informed, structured, evidence-based pathway which will guide them around the costly pitfalls. A pathway based around the safe system approach with buy-in at the top which brings the workforce along. The final step, benchmarking, allows the organisation to measure and track its change.

This symposium will explore the pathway steps for organisations using NRSPP resources to become engaged in road safety. The 'Total Cost of Risk' calculator has been developed by Zurich, tested in Europe by Nestle and modified by NRSPP for Australia. This provides the first crucial step. The next step is a structured approach through the Workplace Road Safety Guide using experts and industry to discuss the preferred safe system approach which can then link into the national Benchmarking Project. The outputs from the symposium can help frame a pathway for organisations to follow through the NRSPP website.

Symposium will be facilitated by Prof. Ian Johnston AM.

Presentation 1 – The Total Cost of Fleet Risk

Presenter: Mervyn Rea

Abstract

The true or total cost of risk is often lost within an organisation. Other Cost Centres are affected. It is very rare for the additional costs to be factored in, or calculated. In most cases, these additional costs are not covered by insurance. Therefore, each crash an organisation experiences often costs significantly more money than is actually paid by the insurance company. When a business comes to understand how expensive a road crash is, it becomes a powerful mechanism to create a proactive culture that reduces the risk of a crash. Some of the indirect costs which are often lost include absenteeism from work, loss of use of a unit/trailer, hiring in costs, lost sales/contracts, staff turnover, low staff morale etc. These are operational costs which must be covered by a business before they can make a profit, so if these costs can be reduced a more profitable business can be achieved.

This presentation will also outline a total cost calculator which helps businesses understand what their organisations total costs are from a crash. The calculator was developed and tested in Europe by Zurich for their customers and is now being made available in Australia through the NRSPP. The tool will help Australian businesses here understand what turnover would be required to cover their total costs from crashes and therefore assist the business case to change fleet safety for the better, and to generate profit from the investment in fleet safety.

Presentation 2 – NRSPP Workplace Road Safety Guide

Presenter: Dr. Darren Wishart and Eric Howard

Abstract:

During the NRSPP's development a consistently asked question by organisations was, I know I have a road safety problem – where do I start?

To answer this question, NRSPP developed the Workplace Road Safety Guide (WRSG). It provides a comprehensive guide for organisational road safety risk mitigation based on the internationally recognised and accepted Safe System approach to road safety. WRSG provides assistance and direction, allowing organisations to identify, research, source solutions, mitigate, monitor and continuously improve road safety within its own sphere of influence. The guide draws on the NRSPP case studies which highlight an organisation's good road safety practice, key lessons learned, evidence and importantly how they did it. The current case studies explore solutions from organisations with anywhere from 10 to 8,000 staff from a range of industries and sectors, what is consistent among them all is that road safety is their top risk and they work to actively reduce it.

This presentation will outline the core themes and principles within the WRSG and how the process can practically assist organisations in implementing a road safety strategy that isn't altruistic but costs effective. The guide was always aimed to remain organic and to grow and develop with the NRSPP. The aim being is to be able to keep the WRSG current as more knowledge is made available and participating organisations willingness to share increases.

Presentation 3 – Panel Session - Examples of good practice translating to a profitable safe business

Presenters

- **Ali Abdurrahman – Origin Energy**
- **Greg Smith – Toll NQX**
- **Mark Stephens – Uniting Care Queensland**

Abstract

Providing a safe working environment should be a central operating principle for any business. However, what is often lost is the understanding that a safe work environment also includes the vehicle. This is a key point of difference for leading organisations as they recognise that the workplace includes the safe movement of its staff and goods. Leading businesses invest in the creation of a safe road culture, both on and off public roads, because it generates a clear cost-benefit over time and helps pay its way. The type of road safety culture is a conscious decision which is created at the top of the organisation.

Whilst the industry and type of business may vary, the process of creating a safety culture is reasonably consistent. In addition the knowledge of how to manage risks is also interchangeable between industries and modes. The degree and level of monitoring between industry sectors may vary between sectors due to

increased regulations in the heavy vehicle sector but essentially businesses are managing similar risks, for example speed, driver behaviour, drowsiness, distraction, third parties, to name a few. Leading businesses actively work with their staff to help jointly create the desired culture.

This component of the symposium will feature a panel session consisting of three leading Australian corporates demonstrating how road safety good practice is practically applied, management of their key risks and the cost-benefits. The organisations include Origin Energy, Toll NQX and Uniting Care Queensland, and each are from entirely different industries and the key themes which emerge will assist in ensuring the WRSG is providing good practice.

Origin Energy Brief

Origin Energy is one of Australia's major energy providing organisations with a mixed fleet of 1000 light and 300 heavy vehicles which travel over a combined distance of 32 million kilometres per annum. It has made a dramatic impact on its business injury rate in 2013-14 with a 23 per cent improvement on Total Recordable Injury Frequency Rate. The most significant achievement came from the LPG business where a concerted focus on leadership, risk reduction and staff involvement resulting in a 33 per cent overall reduction in injuries and almost three consecutive months without a recordable injury.

The LPG business has attributed this achievement to journey management plans to identify and control risks on high-risk routes; introduced GPS-based in-vehicle monitoring systems (IVMS) across the bulk, cylinder and smaller trucks; and a cultural transformation program where employees take ownership for safety themselves and their colleagues.

The business unit has found encouragingly over the past twelve months, motor vehicle accidents in LPG have reduced by more than 50 per cent.

The cultural transformation program called Blue Bus was also introduced at over 30 LPG sites and encourages employee's to display increased ownership of safety. That ownership is increasingly being demonstrated across the business, with employees speaking up to use their "authority to stop an unsafe task", make a record number of behavioural safety observations, and drive improvements in their local processes and procedures.

Toll NQX Brief

Toll NQX, part of Toll Group, operates 400 plus company-owned heavy vehicles across Australia employing in excess of 450 company drivers and more than 1500 when contractors including. For Toll NQX, safety is more than a priority, it's a value. Toll NQX clocks up more than 33 million kilometres per year, safety is also a permanent goal. The organisation is on a path of continuous improvement and always evaluating improvements to assist with incident prevention.

Since the introduction of -vehicle camera systems in its long haul fleet in mid-2011, it was not expecting to shake the conventional wisdom that speed and fatigue are the greatest safety risks for truck drivers. Today, it has compelling evidence that driver distraction also poses a significant incident risk. This insight is changing the way Toll NQX operates its fleet, manages risk, and engages with drivers and contractors.

Uniting Care Queensland Brief

Uniting Care Queensland (UCQ) is one of Australia's largest not-for-profit aged care providers delivering community nursing services in metropolitan, regional and remote Queensland, Northern Territory and northern New South Wales. Operating 4,240 residential aged care beds and providing the equivalent of 1.5 million days of care each year. UCQ also delivers more than 3 million occasions of service annually for community clients in their homes or in its community centres. UCQ fleet has grown to more than 2,400 vehicles that travel 40 million kilometres each year. This includes some staff using their own vehicles. The fleet will continue to grow as demand for more community services increases.

Over the past seven years the UCQ fleet has moved fleet safety from an era where there was no training and minimal focus on crash frequency and driver risk analysis to making fleet safety a core function of the Fleet Management Unit. A holistic approach to road safety across the organisation has created a courteous internal culture which has translated into reduced crash rates through comprehensive risk analysis, driver education, thoughtful vehicle selection, and developing industry partnerships to achieve the desired outcomes.

Viva Energy Brief

Viva Energy believes that every road incident is preventable and is committed to pursuing the goal of no harm to people and protecting the environment. We call this Goal Zero. Our Goal Zero aspiration carries through to our road transport operations by using only transport operators with the same high safety vision as our own. Included in our Goal Zero program are our Life Saving Rules, of which a number are directed at safety on the road. With the training and commitment by our own, and contractor, staff road safety is as important to them as any other part of their job.

Road safety for our company is a systems approach where carriers must ensure vehicles meet the highest safety standards, use up to date in-vehicle technology for driver safety and have a safety management system in place covering driver training, vehicle maintenance, vehicle monitoring, journey management and emergency response. We specify through contractual arrangements the high standards that are to be met by our carriers and we gain assurance that these standards are met or exceeded through a thorough audit process. The expectations we place on our carriers not only ensures the safety of our products, the driver of the vehicle, but also other road users.

Using the Critical Decision Method and Decision Ladders to analyse traffic incident management system issues

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Abstract

Optimising the safety and effectiveness of road crash work environments is challenging. Factors such as traffic, time pressures, and resource shortages combine to provide a dangerous work environment. Added to this, the complexity and interaction of these factors makes it difficult to identify their relative impact. In order to comprehensively understand the source of threats to the safety and effectiveness of the traffic incident environment this study conducted a series of Critical Decision Method (CDM) interviews with operational experts in traffic incident management and the results of the interviews were mapped onto decision ladder templates. Eight operational officers from the Queensland Police Service, Queensland Fire and Emergency Services and the Royal Automotive Club Queensland's (RACQ) Traffic Response Unit were interviewed individually, allowing them to draw on examples from their own experience. Combining the two human factors tools yielded valuable information about decision making processes in the incident management environment. System issues identified in the analysis included intra and inter-agency communication, interoperability issues, training issues, vehicle lighting issues and issues with the uptake of technology. System support solutions aligning with the issues include options for possible training and procedural changes and reviews regarding technology, communication and vehicle lighting.

Introduction

Traffic incident management is the coordinated inter-agency response to an unplanned incident on the road system. It aims to minimise the impact on road users, optimise the safety of incident victims and responders at the scene and manage the flow of traffic until full road capacity is restored. Optimising the safety and effectiveness of traffic incident management has become a significant part of the road safety and traffic congestion solution (Charles, 2007).

Despite the overall road safety benefits, the traffic incident management environment is a critical, temporally challenged, dangerous work environment requiring a high level of collaboration between teams from different organisations. When processes and practices fail to align serious injury or death can result. In the United Kingdom, road works are the cause of 22 deaths and over 800 serious incidents each year (Highways Agency, 2002). In the U.S. an average of one police officer per month is killed in roadside crashes (Fishcher, Krzmarzick, Menon and Shankwitz, 2012). In 2005, of the 98 fire fighters killed on U.S roads, a quarter were pedestrians performing their duties at emergency scenes (FSC, 2012). In

Queensland, Australia, between 2005 and 2009 there were three fatalities and 145 injuries incurred by traffic controllers who were road/railway workers or police (DTMR, 2013).

The injury statistics for responders highlight the need to establish traffic incident management practices that optimise safety and effectiveness at incident scenes. However, it is a complex problem. Typically the incident management teams at a road crash will include Fire and Rescue (focussing on inner cordon scene safety and casualty rescue), ambulance (focussing on saving the lives of road crash victims), police (who act as the scene managers, incident investigators and if required, traffic control), and traffic response units (who specialise in traffic management around the outer cordon of the incident). Representatives from other organisations may attend at some incidents including transport department officials, local government response teams (for example, for biological matter), and volunteer services such as SES and the rural fire brigade. Indirectly these groups are impacted by their separate communications teams. Tow truck operators and media may also be present though not part of the incident management team. Responders are also working with a backdrop of prior decisions in the form of whole of government and departmental policies and legislative requirements and finally, they are required to meet community expectations.

A previous survey of 720 emergency responders from Queensland, Australia investigated their views regarding issues associated with working in the road crash environment (Cattermole, Horberry, Wallis and Cloete, 2014). The results identified issues with passing motorist behaviours and motorist responses to emergency vehicle lighting and incident scene perimeter lighting. Interestingly, results also indicated that many of the issues were related to agency interoperability (inter-agency team collaboration) and communication.

Previous studies investigating mixed-team collaboration and communication in critical environments have mostly centred on military and medical settings, using human factors tools and models to understand critical environments and how to support them. Chen, Sharman, Rao and Upadhyaya (2008) suggested that a multi-layered framework encompassing onsite reactive decisions as well as managerial global-view decisions was required to effectively support emergency response operations. Klein, Calderwood and Clinton-Cirocco (1986) used a knowledge elicitation technique within the theoretical framework of the Recognition Primed Decision (RPD) Model: The Critical Decision Method (CDM), to investigate decisions made by fire fighters in disaster response. They found the technique was an effective tool to understand onsite reactive decisions by experts and CDM has since been used extensively to investigate decisions and system support solutions in critical environments (e.g., Horberry and Cooke, 2010, Klein and Thordsen, 1988, Militello and Lim, 1995). Salmon, Goode, Archer, Spencer, McArde and McClure (2014) successfully used Rasmussen's (1997) Accimapping technique (from his Cognitive Work Analysis (CWA) framework) to evaluate the disaster response for an Australian bushfire. Ashoori and Burns (2013) used chained decision ladders, the template used in the control task analysis (ConTA) phase of CWA, in a 'decision wheel' to measure team collaboration and system support requirements for a medical unit. Results from their work indicated that 'team CWA' can effectively design new teams or determine weaknesses in current team structures.

Although not specifically relating to road crash environments, the mixed teams of medical and military settings and their similarly critical environments indicate that the methods used in the studies may be generalizable to traffic incident management environments.

The current study aimed to expand on the findings of the emergency responder survey by examining incidents in greater depth, investigating the cognitive demands and strategies of the different teams working collaboratively in road crash environments and determining where there may be issues in the current traffic incident management system. To do this, CDM interviews were used to gather detailed information about the strategies of expert decision makers from the Queensland Police Service (QPS), Queensland Fire and Emergency Services (QFES), and RACQ's Traffic Response Unit (TRU) at road crash scenes. In the second part of the analysis decision ladders were used to map the cognitive processes used in decisions of officers at incidents. CDM was chosen as an interviewing technique because of the depth of information attained in past studies from similarly critical environments. The decision ladder was used as it successfully maps cognitive states and processes used in making decisions and can accommodate heuristic and rational processes (Horberry and Cooke, 2013, Lintern, 2011, Naikar, Pearce, Drumm & Sanderson, 2003). CDM and decision ladder templates are conceptually compatible (Lintern, 2011, Naikar, 2010) and have previously been combined in studies related to system support (e.g. Horberry and Cooke, 2013). This was considered an advantage in the current study as it was hoped that the process would not only identify issues in the traffic incident management system, but also possible system solutions.

It was hypothesised that the research would engender a deeper understanding of interoperability and communications issues that emerged from the survey results and offer guidance regarding priority steps towards improving the safety and effectiveness of the traffic incident management environment and processes.

Method

CDM interviews

Participants

Eight CDM interviews were conducted, each generally lasting up to two hours. Participants were experts in their work domain – three traffic response officers from RACQ, three station officers from QFES and two police officers from QPS Sunshine Coast traffic branch.

Each participant was required to choose an incident where they were a decision maker at the scene. The participants were encouraged to think of at least two incidents that were memorable and that had occurred within the 12 months prior to the interview. These were discussed with the interviewer on the day of the interview to determine their suitability for the exercise. In all cases participants' first choice of incident was chosen. The only criteria the interviewer used to establish suitability was that the participant was a decision maker at the scene and that the incident was within the 12 month time frame. All participants worked in an urban environment in SE Queensland so all chosen incidents were urban examples. Incident localities included highway, high speed, high traffic areas and suburban streets. Incident time periods included morning and afternoon peak hour periods, school pick-up time and also in the evening.

Seven participants attended interviews at the University of Queensland in a closed meeting room with access to a whiteboard. One participant was interviewed at his workplace with the same meeting room conditions. Two interviews were conducted with only one interviewer and the other six interviews were attended by two interviewers. In the case where there were two interviewers, the second acted mostly as a scribe throughout the process. Following ethics approval by the University of Queensland, all interviews were audio-recorded.

Procedure

The classic CDM approach was utilised, applying four 'sweeps' of the incident (for a full description of the technique please refer to Hoffman, Crandall and Shadbolt, 1998):

- Sweep 1: Incident identification, selection and elicitation
- Sweep 2: Timeline verification and decision point identification
- Sweep 3: Deep Probes
- Sweep 4: Hypotheticals – What if…?

The interviews were entered into a decision/event table and sweeps 3 and 4 transcribed beneath the table. The deep probes and hypotheticals enabled the interviewer to ask questions about the issues raised and also for the participant's views on how to improve the safety and/or effectiveness of traffic incident management environments with reference to the issues raised.

Decision Ladder

A classic decision ladder template was chosen for the exercise (adapted from Hassall & Sanderson, 2014). The template consists of cognitive processes and states. The cognitive processes enable the decision maker to arrive at the cognitive states. The cognitive states in the template are represented by ovals and the wording for states is identified by nouns. The cognitive processes in the template are represented by rectangles and the wording of processes is identified by verbs.

Each transcript was analysed, mapping decisions onto the decision ladders and coding the decision paths numerically. Each sequence was then tabled to assist in clarity and also to add relevant probe responses next to the cognitive states and processes. Due to space requirements for this paper only one decision ladder is depicted in the results section and tables are not presented in the paper. The example incident was chosen specifically because the key decisions from the participant were mapped onto a single decision ladder template. All other participants required from 2-4 decision ladders for their key decisions.

Once the decisions were mapped, the decision making style was assessed to determine if it was naturalistic or rational and the issues raised throughout the incident were noted for comparison across the group. Information from the deep probes and hypotheticals were added to the tables to enable a deeper understanding of the issues and also assess suggested solutions.

A summary table of the categories of all issues raised and suggested solutions is presented in the results section.

Results

For this paper, one example incident involving a multi-vehicle fatality on a highway and on the border of two police districts is described. Thereafter, summary results from all eight incidents are presented.

The key decisions for the participant mapped onto one decision ladder were deciding to stop the traffic diversion and sending another QPS officer to head off motorists who were about to collide due to a communication issue (see figure 1 below). The communications unit responsible for the participant’s section of the incident was different from the communications unit in another section of the incident as the crash occurred at the boundary of two police districts. One of the communications units released a diversion from one end of the highway but did not inform the communications unit managing the other section of the incident, so northbound and southbound traffic on the highway were traveling towards each other in the same lane. There is no ability for QPS teams working at an incident to communicate with each other or with any other emergency responders on the scene so the officer being interviewed was unable to contact the officers at the other end of the incident scene. Decisions made by the officer were to halt all traffic and request his partner travel lights and sirens to the head of the traffic already in the lane to prevent a collision. The decision style for each decision was naturalistic and probes supported this as the participant based decisions on prior experience and training. Issues raised at the incident were around intra-agency communication, especially at the boundaries of police districts, and the lack of multi-agency incident scene communication ability. The officer was asked his opinion about possible solutions to the communication issues raised in the interview process and he determined that solutions would be around improved communication ability at the scene and between communication units and improved training and processes/policies for communication teams in an operational context.

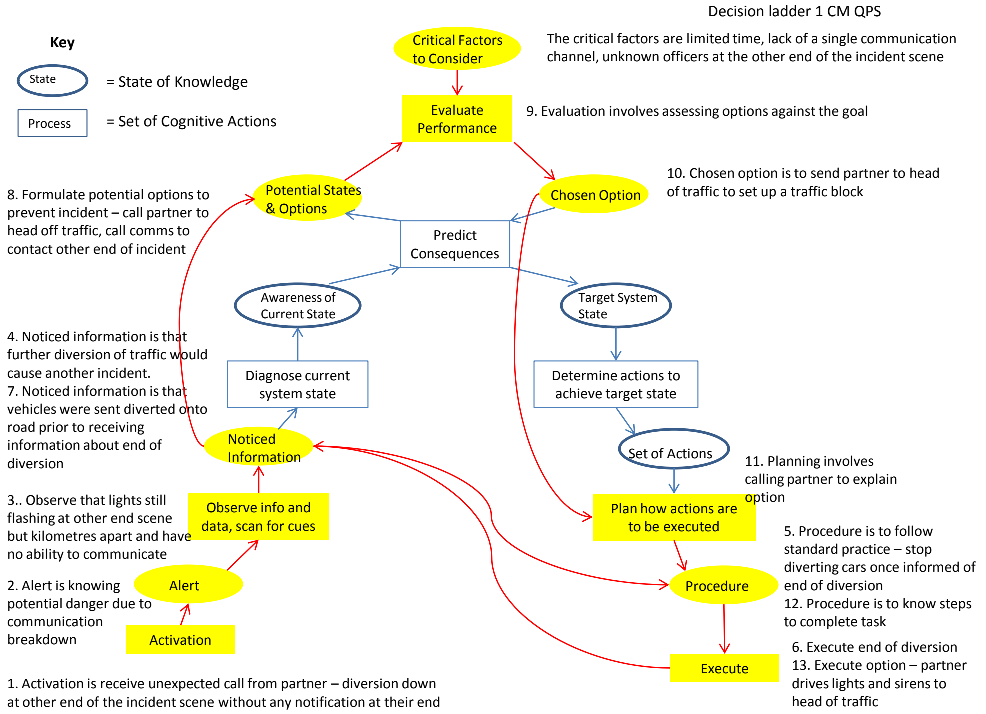

Figure 1. Key decisions for participant mapped onto decision ladder template

Table 1. Summary of results from CDM/decision ladders

Decision Making Issue Identified	**System Support Solutions Suggested by Participants**
Interoperability – misunderstanding roles and responsibilities of TIM responders from other agencies, not being aware of other agency requirements in the environment, non-alignment of agency practices.	Improved training opportunities – inter-agency exercises as well as training focussed on interoperability issues raised
Communication – intra-agency communication issues especially at district borders, incident scene communication within and across agencies, inter-agency communication ability	Investigation of communication technology that better meets incident management requirements
Technology – several examples of where current technological advances provide solutions to TIM issues but there has been no uptake	U.K. and U.S. examples of technology linking TMC to GPS offering emergency responders the quickest routes to incidents and reducing congestion impacts. New technology for training includes virtual training environments and the use of YouTube. A review of technology relating to communication is required.
Vehicle Lighting – when responders with amber flashing lights are the only ones at the scene or the only lights visible to oncoming motorists, the warning is not motivational/significant enough to reduce motorist driving speeds	A review of amber lighting for responders while at traffic incidents. Motorist education program

The summary table above outlines results from the eight interviews and analyses. The issues identified in the CDM/Decision Ladders were identified and then probe questions established participant perspectives about possible solutions to the issues raised. Issues raised were interoperability, communication, technology and vehicle lighting.

Discussion

The traffic incident management environment can be thought of as a single system. However, it is supported by policies and directives from separate agencies, departments and industry, each developed with a focus on one aspect or group of the incident management system rather than the system as a whole. It is likely, therefore, that some policies and practices will not be compatible. These incompatibilities may not have an immediate visible effect, but establish the potential for accidents. The aim of this study was to determine if using two human factors tools – CDM interviews and decision ladders, would successfully identify issues stemming from ineffective or incompatible policies and practices in the traffic incident management environment.

In the example incident outlined in the results, the CDM interview and decision ladder successfully identified intra-agency communication and procedural issues at police district boundaries and established the potential impact of the non-optimal communications procedures at QPS. The method also offered the officer (an operational expert) the opportunity to determine logical solutions matching the issues. In this case the officer suggested a requirement for improved communication ability within and between agencies at incidents and improved training, policies and processes for communication teams at QPS. The results indicate that this technique could provide valuable information for incident investigations and in reviews of policies and procedures for operations.

More generally, the combination of CDM interviews and decision ladder template for mapping decisions effectively described strengths and issues at the eight road crash work environments described by participants. All participants were highly experienced in the road crash environment and their decision styles were naturalistic. They displayed adaptability when faced with non-typical or non-optimal situations and also when the performance from other decision makers in the environment was non-optimal. They relied heavily on their training, processes and policies, and past experience in similar situations. When asked through ‘what if’ questions in the CDM interview process what issues a less experienced officer would face in the situations described by participants, each could point to aspects of the environment that could be made more effective or supportive and that could potentially lead to accidents at the scene if decision makers were not experienced and/or adequately trained. The issues raised by participants fell into the four categories listed in Table 2: interoperability, communication, technology and vehicle lighting.

The interoperability issues raised were related mainly to frustrations when other agencies’ actions at the scene were detrimental to their own agency’s requirements. For example, QAS do not have any training in incident command and go straight to the casualties at the scene, which can be frustrating to incident commanders from QFES or QPS, reduces the effectiveness of the incident management system and could potentially lead to responder injuries. Solutions offered by participants to improve interoperability issues were increasing the number of joint exercises and developing an inter-agency course to improve understanding of all agency requirements and how they can effectively work together. The suggested solutions from participants seem logical. Currently station officers at QFES are required to attend one exercise per year. One participant suggested that unless officers are self-motivated and follow up with their own training, the level of joint training is insufficient. It is interesting to note that Queensland Rail, who experienced similar interoperability issues during incidents, increased their joint exercises from one per year (the legislative requirement) to 22 per year and have noted a significant decrease in interoperability issues with improved response times and outcomes (QR Security Unit, personal communication, 2015).

Aside from the internal communication issue noted in the decision ladder above, all other communication issues raised by participants related to inter-agency communication in general and also at large incident scenes. As a general inter-agency communication example, one participant with local knowledge of road and traffic conditions noticed another agency choosing a non-optimal route to an incident but was unable to contact them to correct their decision. As a result that agency arrived at the scene 15minutes later than the other agencies. Communication ability for all responders working at a specific incident would also improve the safety and effectiveness of road crash work environments. For example, one participant discussed an incident where a road work traffic controller was commandeered to manage traffic at one part of the incident. Due to the size of the incident precinct, there was no way to check on him. The participant was concerned about the risk of leaving the road worker unsupported at the scene as he was untrained in dealing with road crash environments and had also recently completed a full shift of his own work so was likely to be fatigued. All participants suggested that communications technology enabling multi-agency communication was a solution to communication issues for emergency responders.

Technology issues raised by participants related to a lack of uptake of current technology by agencies and government departments. Participants mentioned U.K. and U.S. examples of technology linking traffic management centres and communication teams with GPS technology that provides fastest routes for emergency vehicles to incident scenes. Using better technology in training was also cited by participants as an area needing improvement. For example, training recruits using virtual environments and using video footage from YouTube or CCTV on vehicles to train officers in decision making in critical environments.

The amber flashing lights of the TRU were identified in interviews as inadequate in situations where oncoming traffic could only see the amber lighting instead of blue/red flashing lights – for example when incidents occurred on the other side of a hill or around a corner. One participant described an incident in which he was required to park his TRU vehicle at the top of a hill to move traffic out of a lane so that he could attend to a casualty in the lane. Vehicles moved from the lane but continued to drive at high speed in the lane next to him while he was conducting CPR on the casualty. Another participant described an incident where police vehicles were stationed at corners out of sight from his TRU vehicle. Motorists did not attend to the cones and arrow board directions from his vehicle, driving over them and into the incident scene. Participants suggested a review of TRU vehicle lighting while at an incident is required. Previously SES and rural fire brigade vehicles were also restricted to amber flashing lights. However following a review they are currently in the process of changing to blue/red flashing lights at incidents. It is likely a similar review is necessary for TRU vehicle lighting at traffic incidents.

The study's participants were all based in an urban environment which possibly limits the generalizability of the study to regional or rural environments. A possible future study could replicate the methodology with participants from regional and rural emergency response teams. Another possible limitation in the study is that participants chose their own incident. This may have biased the study as the participants would perhaps be more likely to remember incidents where there were a higher number of issues. However, given that the participants all had numerous examples of potential incidents it is unlikely that the results were significantly affected. To test this, a future study could restrict the choice of incidents to within the previous month rather than 12 month period.

Although this study identified issues in the traffic incident management system, it did not investigate higher level decisions to determine where policies and processes might be impacting the incident management system negatively. Also, each of the participants discussed separate incidents, so it was impossible to fully understand if what seemed like non-optimal choices from other agencies according to the re-telling of the participant, was actually a decision within the framework of their agency's polices and directives, indicating a higher level incompatibility rather than human error at the operational level. In future studies, it would be beneficial to map relevant agency and department policies, directives, regulations and legislation onto an accimap to develop a holistic picture of the traffic incident management system. Another important future study will be to investigate a single incident and interview the decision makers from each of the agencies who attended that incident.

Conclusion

The thought processes and decisions of experts in the traffic incident environment are a rich source of information for anyone interested in incident management system design. The current study identified several system flaws and system support solutions. The combination of CDM interviews and decision ladder template offered an excellent tool to represent decisions and identify points where system re-designs could be beneficial.

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Elderly Drivers and Emergency Department Visits

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Abstract

Background: Canadians are living longer and have more active lifestyles, which means that there are more elderly drivers and increasing road traffic injuries among this population. The primary objective of this study was to examine the injury profile and emergency healthcare utilization of older drivers (age ≥70) treated in an emergency department (ED) after a motor vehicle crash (MVC).

Methods: We conducted a retrospective cross-sectional study with data obtained by chart reviews of MVC related ED visits at Vancouver General Hospital, British Columbia from January 1, 2009 to May 31, 2014. Each older injured driver (age ≥70) was matched with 2 younger injured drivers (age <70) with the closest ED visit date and time. Data from medical records including demographics, crash circumstances, injury profile and ED care information were analysed using descriptive and logistic regression analyses.

Results and Conclusions: Elderly drivers were 2.41 times more likely to be admitted to hospital and sustained more injury after a crash compared to younger drivers. As expected, elderly drivers also had longer ED length of stay compared to younger drivers (median time: 184.5 versus 155 minutes) as well as higher rates of ambulance arrival (85.4% versus 68.3%), blood work requirement (63.5% versus 39.3%) and diagnostic imaging (78.1% versus 62.8%).

Implications: Compared to younger drivers, elderly drivers involved in MVCs sustain more serious injuries and have higher healthcare utilization. These indicate the need for programs to identify at risk elderly drivers and ED treatment protocol to care for the increasing older driving population.

Introduction

Currently, the leading cause of injuries requiring hospital care in the older adult population is falls. However, over the next few decades, we are likely to see increasing numbers of motor vehicle crash (MVC) related injuries as the older population continues to be active on the road. In the province of British Columbia (BC), the number of drivers aged 70 years and above is projected to increase by over 100% from 320,000 in 2012 to 670,000 by 2032 based on the current numbers of licensed drivers and their age distributions in 2002-2012 (data from Insurance Corporation of British Columbia). It is anticipated that emergency department (ED) visits by this driver group will also rise significantly.

The elevated crash and injury risks of elderly drivers have been studied previously (Bauza, Lamorte, Burke, & Hirsch, 2008; Newgard, 2008; Welsh, Morris, Hassan, & Charlton, 2006). These studies show that elderly drivers are more likely to be injured or killed in a crash and more likely to be hospitalized with longer length of stay compared to their younger counterparts. This is mainly due to the fact that older persons have decreased physiologic reserve to respond to injury in the event of a crash, even in crashes that are considered minor (Augenstein et al., 2005).

While crash rates per vehicle distance traveled are higher in elderly drivers with advancing age (Langford, Koppel, McCarthy, & Srinivasan, 2008; Ryan, Legge, & Rosman, 1998), some studies noted that fragility from aging is by far the most important factor for the increased risk of serious injuries and fatalities in this age group (Li, Braver, & Chen, 2003; Meuleners, Harding, Lee, & Legge, 2006). Using US national accident data, Li found that fragility started to increase at around age 60 and accounted for 60-95% of excess mortality rate per vehicle distance travelled. Among older drivers, significant increase in injury crash involvement did not begin until the age of 75 and explained at most 30-45% of the elevated fatal injury risk in this group of drivers. This is consistent with an Australian study (Meuleners 2006) which reported that fragility contributed to 47-95% of injury risk in drivers aged 65 and above. Although excess crash involvement was a major contributing factor for drivers aged 80 and above, fragility still accounted for about 60-70% of their fatal injury risk. In Canada, with data from police reports, Zhang (2000) also showed that pre-existing medical or physical conditions increased the risk of fatality by a factor of 3.5 - 5 for drivers age 75 and above (Zhang, Lindsay, Clarke, Robbins, & Mao, 2000).

Besides age related fragility, a number of additional factors can also affect injury outcomes in a crash. Zhang reported that higher fatal injury risk is associated with high speed roads (odds ratio= 7.9), head-on collisions (odds ratio= 55.1), single vehicle collisions (odds ratio= 6.7) and two vehicles turning collisions at intersections (odds ratios= 3.1 to 8.7). Fortunately, per capita serious crashes involving elderly drivers remain low. A more recent study on the patterns of crashes by elderly drivers has suggested that they are mostly involved in minor crashes (Trieu, Park, & McFadden, 2014). Rear-end collisions, same direction side swipes and right angle collisions (particularly right angle collisions at intersections) are most frequently observed in elderly drivers. A telephone survey by Betz (2010) indicated that most crashes involving elderly drivers occur under relatively safe conditions such as during the day, in good weather, and on dry roads (Betz & Lowenstein, 2010). The resulting injuries would be expected to be minor if not for the driver's advanced age and physical frailty.

Most prior literature on crash and injury rates of elderly drivers are based on data from police reports, hospital separations or surveys and have primarily focused on fatal and severe injury crashes. A recent study by Vogel and colleagues (2013) reported that the majority of older MVC patients treated in an emergency department sustained only minor injury and did not require hospital admission (Vogel, Ginde, Lowenstein, & Betz, 2013). However, many older MVC patients have moderate to severe pain when discharged home from the emergency department and may require ongoing medical care as outpatients (Platts-Mills, Hunold, Esserman, Sloane, & McLean, 2012). Our group also reported that, although not requiring hospital admission, drivers involved in minor injury crashes often have slow recovery (Brubacher et al., 2014). Details on patients with minor injuries (i.e. discharged from the ED), and information on their post ED care is not captured in hospital separation data and police reports.

The study by Vogel (2013) indicated that adults (age >65) have higher rates of MVC related ED visits and serious injury compared to the younger cohort (age 18-65). Older patients also require greater acute care and rehabilitation resources. The major limitations of Vogel's study are the lack of information on driver versus passenger status, crash circumstances and pre-crash health status. The recent decline in fatal and severe injury crash rates among elderly drivers is thought to be due, at least in part, to the improving general health status of older individuals and safer modern vehicles (Cheung & McCartt, 2011; Cheung, McCartt, & Braitman, 2008).

There is little data on emergency care utilization of elderly drivers after minor crashes. Given their age related fragility and higher likelihood of injury, we hypothesize that, after minor crashes, older drivers (age ≥70) will require more emergency care resources than younger drivers. Our primary objective was to provide current BC data on the emergency care utilization of elderly drivers (age ≥70) after motor vehicle crashes. Specifically this study (1) examined the injury profiles and emergency care utilization of elderly drivers compared to that of younger injured drivers, and (2) explored factors that are potentially associated with injury level of elderly drivers using hospital admission as surrogate indicator of injury severity.

Methods

Data and Population: This study was approved by the University of British Columbia Research Ethics Board and by the Vancouver Coastal Health Research Institute. We included all drivers aged ≥70 years (elderly drivers) who were injured in a motor vehicle crash and presented to Vancouver General Hospital (VGH) emergency department (ED) between January 1, 2009 and May 31, 2014. VGH is the largest level 1 trauma centre in British Columbia and the VGH ED has 85,000 visits annually including approximately 1100 injured drivers. Among these injured drivers, on average 55 per year were ≥70 years old. Injured drivers were identified through the VGH ED database. For comparison, we systematically identified drivers aged < 70 years (younger drivers) and presented to VGH ED during the same period. For each older driver, we selected 2 younger drivers who visited the VGH ED after a car crash at the closest date and time to the visit of the older driver. These drivers formed the younger driver comparison group. The matching of ED dates was done to control for unmeasured driving conditions (weather and seasonality) and trends in care utilization as well as for sampling efficiency. Ideally we should match crash characteristics and pre-existing health status; however, that information is not available until the charts have been reviewed.

Drivers who presented directly to VGH ED from crash sites by ambulance or were self-admitted within 2 days of an MVC were included in this study. Drivers who were transferred from other hospitals were excluded in order to avoid missing ED visit information and bias from over-inclusion of more severely injured cases. Motorcyclists and scooter users were also excluded in this study because they represented a different at risk population of road users.

Data for this study came from review of medical records. We collected demographics (age and gender), crash time and date, mode of ED presentation (self-admitted versus by ambulance), date and time of ED presentation, description of crashes (e.g. single versus multi-vehicle crash), pre-crash medications, pre-crash medical history, injury severity (maximum Abbreviated Injury Scale (AIS) score), injury area by body region, ED investigations, ED length of stay, and hospital admission. In order to standardize our injury classification we categorized injuries by anatomical location and used the maximum AIS score to indicate overall injury severity (Gennarelli & Wodzin, 2006; Greenspan, McLellan, & Greig, 1985).

Statistical analysis: For objective 1, we conducted cross-sectional descriptive analyses on the injury profiles, ED care utilization, hospital admission, pre-crash medical history and crash circumstances for both driver age groups. The medians and interquartile ranges (IQR) of age and ED length of stay (LOS) were determined. For categorical variables, we compared proportions with Chi square test and estimated the association by reporting crude odds ratios (OR) with 95% confidence intervals (CIs). For continuous variables, we used the nonparametric K test on equality of medians.

For objective 2, we examined the association between driver age groups and hospital admission by conditional logistic regression adjusted for gender, crash location (roads with low versus high speed limits), crash type (single versus multi-vehicle), crash time (daytime versus night time, weekend versus weekday), and pre-existing health conditions. Potential risk factors for hospital admission were selected a priori according to bivariate analyses and theoretical considerations. An inclusive modelling approach was used to identify a parsimonious group of important factors independently associated with the likelihood of hospital admission. Factors that were statistically significant at the $p<0.10$ level on bivariate analysis were assessed during the model building process. Factors were considered for inclusion in the parsimonious model if they produced at least a 10% change in effect size for age group related outcome (i.e. hospital admission) odds ratio. We also conducted a subgroup analysis restricted to multi-vehicle crashes to examine the association between hospital admission and crash configuration (angle impact versus head on, rear-end, etc.). Conditional multivariable logistic regression on each outcome was conducted separately. All analyses were performed using Stata version 12.0 (Stata Corp., College Station, TX)

Results

Between January 1, 2009 and May 31, 2014, 238 elderly drivers aged ≥70 were treated for MVC related injuries. Of these drivers, 16 who were transferred from other hospitals and 3 who delayed their ED visits for more than 2 days after the crash were excluded. The remaining 219 injured elderly drivers were included for analysis and matched with 438 younger drivers who formed the comparison group.

The median ages were 78 (IQR:73-82) years and 38 (IQR:28-51) years for the older and younger driver groups respectively (**Table 1**). Male drivers were equally distributed in both age groups. As expected elderly drivers were more likely to have at least one pre-existing health condition (crude OR=10.3, 95% CI: 6.08-17.4), and have used at least one prescription medication during the 30 days prior to the crash (crude OR=6.08, 95% CI: 3.96-9.33). Compared to younger drivers, more elderly drivers were involved in daytime crashes (83.6% versus 69.4%) and in single vehicle crashes (27.9% versus 17.0%) but fewer were involved in rear-end crashes (14.8% versus 27.4%). The rates of seatbelt use were very high (>90%) in both age groups.

Table 1: Demographics and Crash Characteristics of Study Population

Demographics	**Younger (438) N (%)**	**Older (219) N (%)**	**Crude Odds Ratio (95% Confidence Interval) Ref = Younger drivers**
Age (median, IQR)	38 (28 - 51)	78 (73 – 82)	-
Male	217 (49.5)	124 (56.6)	1.35 (0.97-1.90)
Health conditions‡	192 (43.8)	193 (88.1)	10.3 (6.08-17.4)
Any pre-crash medications	193 (44.1)	182 (83.1)	6.08 (3.96-9.33)
Crash Characteristics			
Weekend crashes	120 (27.4)	62 (28.3)	1.15 (0.61-2.17)
Daytime (6am-6pm)	304 (69.4)	183 (83.6)	2.49 (1.59-3.88)
Single vehicle crashes	74 (17.0)	61 (27.9)	1.77 (1.22-2.56)
Angle impact crashes	186 (42.9)	94 (43.3)	1.01 (0.73-1.40)
Head-on crashes	25 (5.76)	18 (8.29)	1.50 (0.79-2.85)
Rear-end crashes	119 (27.4)	32 (14.8)	0.45 (0.29-0.67)
Unbelted drivers	24 (5.5)	8 (3.7)	0.66 (0.29-1.48)
Low speed road crashes	399 (91.1)	204 (94.0)	1.53 (0.80-2.97)

‡ Any pre-existing health conditions

The majority of drivers sustained only minor injuries (65%) or no documented injury (22%) while 17.4% of older and 10.5% younger drivers were classified as having moderate to severe injuries (max AIS score $\geq$ 2). Among those with higher injury levels, only one driver in the younger group was severely injured (max AIS score =5) and most were moderately injured (max AIS score = 2). Most drivers from both groups were treated and released from ED directly. Nevertheless, the unadjusted odds of hospital admission for elderly drivers (19.6%) were 2.66 times greater than for younger drivers (8.2%) (crude OR= 2.66, 95%CI: 1.69-4.40) (**Table 2**). However, 10 of the 43 admitted elderly drivers were admitted for acute exacerbation of pre-exiting medical conditions including seizures (1), syncope (5), stroke/angina (3) and brain lesion (1) rather than for their injuries sustained in the crash. Elderly drivers were also more likely than younger drivers to sustain torso injuries (crude OR=2.16, 95% CI: 1.46-3.20).

Table 2: Injury Profiles and Emergency Care Utilization

	Younger Drivers N (%)	**Elderly Drivers N (%)**	**Crude Odds Ratio (95% Confidence Interval)**
Injury Profiles			
Head and neck	164 (37.4)	77 (35.2)	0.90 (0.64-1.28)
Torso	67 (15.3)	62 (28.3)	2.16 (1.46-3.20)
Extremities	101 (23.1)	57 (26.0)	1.17 (0.81-1.70)
Back and spine	67 (15.3)	19 (8.7)	0.52 (0.31-0.90)
C-Spine fracture	7 (1.6)	6 (2.7)	1.73 (0.58-5.22)
Max AIS score ≥ 2	46 (10.5)	38 (17.4)	1.80 (1.13-2.89)
Hospital admission	36 (8.2)	43 (19.6)#	2.66 (1.65-4.28)
Emergency Care Utilization			
CT scan	119 (27.2)	104 (47.5)	2.42 (1.71-3.40)
X ray	248 (56.6)	157 (71.7)	2.04 (1.41-2.94)
Ultra sound	22 (5.1)	9 (4.1)	0.81 (0.37-1.79)
Echocardiogram	2 (0.5)	5 (2.3)	5.00 (0.97-25.8)
Any imaging	275 (62.8)	171 (78.1)	2.18 (1.48-3.12)
Bloodwork	172 (39.3)	139 (63.5)	2.62 (1.87-3.68)
Ambulance	299 (68.3)	187 (85.4)	2.58 (1.70-3.91)
ED LOS (median, IQR) ‡	155 (101 -221)	184.5 (130 -257)	P< 0.0001*
Medications given in ED†	260 (59.4)	119 (54.3)	0.82 (0.60-1.13)

‡ Length of stay (LOS) in minutes of those discharged from emergency department
† Any medications given at emergency department
# 10 of the 43 elderly drivers were admitted for other medical reasons (crude odds ratio became 2.03, 95%CI:1.22-3.6 when these 10 patients were excluded).
***** In comparison with younger drivers by nonparametric K-sample test on equality of medians

In terms of emergency care utilization, elderly drivers were more likely to be brought to ED by ambulance (crude OR=2.58, 95%CI: 1.70-3.91), to have longer ED length of stay (median LOS 184.5 versus 155 minutes), to require computerized tomography (CT) (crude OR=2.42, 95% CI: 1.71-3.40) or X-ray (crude OR=2.04, 95% CI: 1.41-2.94) imaging procedures, and to have blood work ordered (crude OR=2.62, 95% CI: 1.87-3.68) (**Table 2**).

Bivariate analyses of the association between hospital admission and potential risk factors indicated that (1) older age group, (2) being male, (3) pre-existing health conditions, and (4) single vehicle crashes were significantly associated ($p<0.05$) with an increased likelihood of being admitted to hospital while (5) seatbelt use and (6) crashes on low speed roads were associated with a decreased hospital admission rate. All significant factors from bivariate analyses (except seatbelt use) were also found to be significant predictors in the multivariable analysis on hospital admission (**Table 3**).

Table 3: Factors Associated with Hospital Admission of Drivers Treated in Emergency Department and Adjusted Odds Ratios

	All crashes		**Multiple vehicle crashes only**	
	All hospital admission	Crash related admission	All hospital admission	Crash related admission
Older driver	2.41 (1.28-4.56)	1.82 (0.93-3.58)	6.02 (1.89-19.1)	4.13 (1.24-13.7)
Male	2.44 (1.13-5.28)	2.39 (1.07-5.34)	4.33 (1.10-17.1)	4.93 (1.10-22.0)
Low speed road	0.30 (0.11-0.85)	0.34 (0.12-0.95)	0.14 (0.02-1.10)	0.17 (0.2-1.42)
Health condition	2.21 (0.95-5.17)	2.17 (0.91-5.14)	2..92 (0.86-9.87)	2.51 (0.68-9.19)
Single vehicle	5.57 (2.33-13.30)	5.44 (2.67-13.1)		
Crash type				
Angle crash			1.00	1.00
Head-on			7.37 (0.91-59.1)	9.25 (0.98-89.4)
Rear-ended			0.82 (0.22-3.03)	0.54 (0.12-2.39)
Other			0.23 (0.03-1.93)	0.24 (0.03-2.09)

Compared to younger drivers, the odds of hospital admission among elderly drivers were 2.41 times higher (OR=2.41, 95%CI: 1.28-4.56) after controlling for gender, low speed road crashes, pre-existing health conditions and single vehicle crashes. However, driver age group became non-significant when the 10 drivers who were admitted primarily for medical conditions were excluded from the analysis, although a trend towards a higher admission rate remained for the older driver group (**Table 3**).

In subgroup analyses restricted to multi-vehicle crashes, driver age group was a statistically significant factor for both 1) all hospital admissions, and 2) crash related admissions. Head-on collisions tended to be associated with a higher rate of hospital admission than other types of crashes (**Table 3**). It should be noted, however, that these estimates are not reliable and have wide confidence intervals because of too many uninformative sets in this sample. These results should therefore be interpreted with caution.

Discussion

Many have predicted an increasing number of road traffic injuries as older road users continue to be active on roadways (Bedard, Stones, Guyatt, & Hirdes, 2001; Lyman, Ferguson, Braver, & Williams, 2002). Emergency departments are likely to see more injured elderly drivers over the next few decades. Examining crash circumstances, injury profiles and care utilization will help understand and manage the increasing need of emergency care for this population.

The driving environment may explain some of the injury levels and crash profiles of the elderly drivers in this study. Most crashes occurred in the Metro Vancouver area, a major urban centre with heavy traffic volume and relatively low vehicle speed, particularly during the daytime hours. In this study, 94% of crashes by elderly drivers occurred on roads classified as low speed. Compared to younger drivers, there were significantly more daytime crashes in the elderly driver group (**Table 1**). The majority of crashes in both age groups involved another moving vehicle(s) but elderly drivers were more likely to be involved in single vehicle crashes compared to younger drivers (27.9% versus 17%).

Interestingly, we found that, compared to younger drivers, elderly drivers were less likely to be involved in rear-end collisions but more likely to be involved in head-on collisions (**Table 1**). Braitman and Kirley (2007) studied intersection collisions and reported that drivers aged >80 had fewer rear-end collisions compared to younger age groups (age 35-34 and 70-79) but had more failure-to-yield crashes (Braitman, Kirley, Ferguson, & Chaudhary, 2007). Their study was based on police reports and phone interviews with at fault divers. They defined rear-end crashes as occurring when the participant's vehicle ran into the other vehicle. Their "failure-to-yield crashes" would probably be equivalent to head-on collisions when both vehicles collided on the front ends. In our study, crash information was recorded by paramedics or triage nurses often based on patient's own description. Nevertheless, the crash involvement characteristics of elderly drivers in our study appear to be similar to that reported by Braitman and Kirley. Unfortunately information on whether or not crashes occurred at an intersection was not consistent recorded in hospital charts. It appears that elderly drivers in this study frequently drove in local roadways in the city, and were more often involved in low speed crashes. Starting up from a stop, going straight at stop signs, and negotiating turns present the most risk among elderly drivers (Preusser, Williams, Ferguson, Ulmer, & Weinstein, 1998). It is also known that elderly drivers are more likely to confuse gas with brake pedals and sometimes accelerate unintentionally (Freund, Colgrove, Petrakos, & McLeod, 2008). Underestimating the speed of an approaching vehicle is another common cause of intersection accidents among elderly drivers (Braitman et al., 2007; Scialfa, Guzy, Leibowitz, Garvey, & Tyrrell, 1991). In any case, most crashes involving elderly drivers in our study are probably minor since most occurred on low speed roads during the daytime hours as shown in **Table 1**.

Consistent with findings reported by others (Koppel, Bohensky, Langford, & Taranto, 2011; Yee, Cameron, & Bailey, 2006), elderly drivers in this study were more likely to sustain torso injuries compared to younger drivers although, in both age groups, we found a higher proportion of head & neck injuries than previously reported. The higher proportion of torso injury in elderly drivers could be due to age related osteoporosis which causes higher risk of rib fractures, particularly in head-on collisions. Younger drivers were however more likely to suffer head and neck injuries probably resulting from their higher rates of rear-end collisions.

Elderly drivers were more likely to be transferred by ambulance (**Table 2**). They were also more likely to require diagnostic imaging and bloodwork. The higher rates of emergency care in elderly drivers that we observed are also consistent with other studies (Lotfipour, Cisneros, & Chakravarthy, 2013; Vogel et al., 2013). However, we do not know whether the higher care utilization in the elderly driver group is because of worse injuries or because of increased health concerns related to advanced age. Overall, the hospital admission rate, a surrogate indicator of injury severity, was higher in elderly drivers even after excluding those admitted for pre-existing health conditions unrelated to injuries sustained in the MVC (although this association was no longer statistically significant after these cases were excluded) (**Table 3**). Our findings are consistent with previous studies indicating that age related frailty is important for predicting injuries and requirement for hospital admission. Although 88% of elderly drivers in this study were reported to have at least one health condition, most of these conditions were probably not serious enough to affect their driving abilities or injury outcomes because less than 20% required hospitalization.

Limitations

In this study we matched elderly drivers with a comparison group of younger drivers according to dates of ED visit only. Better matching may have been achieved if we also matched for crash characteristics. With conditional logistic regression, the non-informative match sets were not used for estimation. It appears that crash type in this sample have a few of these concordant pairs potentially making the regression estimates unreliable. Nevertheless, the results still suggested that being older (age ≥70 years) is statistically significantly associated with higher injury severity by all measures.

Medical records typically have limited details on crash circumstances such as striking or struck vehicle status. Missing data or misclassification regarding crash types or vehicle speeds is also a concern. In this study, we carefully read all descriptions of injury mechanism from discharge notes, trauma team records, and ambulance records in order to minimize missing data, but misclassification could still occur. Instead of analysing vehicle speeds (which were inconsistently reported), we categorized crash locations into high speed roads (≥ 60km/hour) and low speed roads (<60km/hour) based on actual crash locations. However, some crashes on high speed roadways may still occur at low speed and vice versa.

Pre-existing medical history is based on triage nursing or trauma consultation notes. In some instances, this information may not be recorded in the medical record, especially for younger drivers and those with minor injuries. We considered the patients with no recorded pre-existing medical problems to be healthy. For simplicity, we have not grouped medication and medical history into specific health conditions such as cardiovascular or neurological conditions. This is unlikely to affect driving and injury outcomes if conditions are mild. In addition, we do not know whether self-regulation might play a role in our samples. Drivers with pre-existing health conditions may choose to drive if they feel that their conditions do not affect their driving ability or because of necessity.

This study examined injuries of elderly drivers resulting from mostly minor crashes occurring in an urban area. Our findings may not be generalizable to crashes that occur outside of major urban centres. Future research should also include trauma centres serving smaller urban and rural locations.

Conclusions

As expected, elderly drivers sustained higher rates of injuries when compared to younger drivers although most crashes and injuries in this study were considered minor. Compared to younger drivers, the odds of hospital admission among elderly drivers were about 2.41 times greater after adjusting for gender, pre-existing health condition and crash type. Elderly drivers were also likely to use more emergency care resources. Evaluation of injured elderly drivers may require specific considerations of changes in their physical conditions (i.e. frailty) as well as crash circumstances.

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Too fast for these conditions? Factors influencing drivers' choice of speed

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Abstract

The choice of inappropriate speeds by drivers is one of the oldest and most difficult road safety issues. This paper describes the results of two experiments investigating the factors influencing drivers' choice of speeds on rural roads. In the first experiment the influence of trip purpose and individual differences on speed choice was examined. The results showed large differences between speeds chosen for different driving purposes; the lowest speeds were chosen when the goal was economy and the highest when driving for fun. In addition, there were individual differences in speed preferences such that some drivers indicated that their usual speed was above what they believed was a safe speed while others indicated that they usually drove even slower than what they thought was safe. The second experiment investigated the relationship between the visual appearance of rural roads and drivers' choice of speed on those roads. Previous research has shown that how a road looks can affect drivers' perception of their speed, and as a result influence the speed they choose, in some cases without them being aware of it. In this experiment drivers completed a picture sort task and then indicated their preferred speed, safe speed, and likely speed limit for 34 rural road scenes. The results indicated that perceived difficulty was the best predictor of participants' speed choices. The results are discussed in terms of identification of road characteristics that can help distinguish behaviourally relevant road categories and produce better speed compliance independently of enforcement.

Introduction

Traffic crashes represent a worldwide problem and drivers choosing speeds that are too fast for the conditions has been regarded as a main contributor to this problem (af Wåhlberg, 2006). Speed limits and their enforcement have been the most widespread attempt to make drivers choose safe speeds (Elvik, 2010). In spite of enforcement and safety campaigns 50 % of drivers are reported to break the speed limit every day (Yannis, Louca, Vardaki & Kannelaidis, 2013). This non-compliance suggests that other factors are involved in drivers' speed choice.

These factors appear to include some combination of drivers' motivations and purpose for the trip and expectations and habits formed from prior exposure to the roads they are travelling. It has been widely acknowledged that drivers have very different reasons for driving, and that these different goals have a significant influence on drivers' speed choices (Michon, 1985). In one study, roadside interviews revealed that different driving goals (or motives) were associated with substantially different speed choices (Shinar, 2001, cited in Oppenheim & Shinar, 2011). The highest speeds were chosen when drivers were asked to select a speed that would maximise pleasure or the fun of driving. The lowest speed choices occurred when drivers were asked to consider economy or safety.

The visual features of the road, and drivers' familiarity with them, also play an important role in drivers' speed choice. Weller, Schlag, Friedel, and Rammin (2008) asked participants to rate and sort photographs of a variety of rural roads. Participants tended to group rural roads into three broad categories based on lane width and road markings and these categories successfully predicted participants' ratings of the appropriate speed for each road. Investigating the effects of familiarity on driver behaviour, Charlton and Starkey reported that as drivers' amount of practise with a simulated rural road increased, their speed choice became increasingly consistent (Charlton &

Starkey, 2013). Changes to the visual appearance of familiar roads, without any changes to the road geometry, led to increased ratings of driving difficulty and greater speed variability.

Better understanding of these (sometimes conflicting) motivations underlying drivers' speed choices may be a key to addressing the problem of speed heterogeneity and non-compliance with speed limits. The goal of the present research was to extend the research described above by: 1) comparing drivers speed preferences (the speed drivers' like to drive at when motivated by different trip purposes) across a range of familiar rural roads; and 2) to identify the road features that most influence drivers speed choices using picture-sorts and subjective ratings of familiar rural roads.

Experiment 1

Method

193 drivers (96 male, 96 female, 1 who preferred not to indicate gender) were approached in car parks at five locations. Participants' ages ranged from 17 to 85 years (*M* = 43 years, *SD* = 15.6), and the majority of the participants held a full driving license (full license, *n* = 160; restricted license, *n* = 27; and learner's license *n* = 3). Ethical approval for the recruitment and test protocols was received from the School of Psychology Research Ethics Committee at the University of Waikato.

Drivers were approached with a verbal invitation to participate in a short questionnaire as they were walking from their cars. Drivers were then asked several questions about the road they had just used to reach the interview location, including: what speed they had just driven on that road (self-reported speeds); what speeds they would prefer to drive on that road to save money on fuel (eco speed); to drive safely (safe speed); to maximise the fun of driving (fun speed); and their usual speed on that road (usual speed) (as in Oppenheim & Shinar, 2011). Participants were then asked what they thought the posted speed was on that road (speed limit belief).

Results

The participants' speed ratings for roads with 100, 80 and 60 km/h limits are shown in Figure 1. As can be seen in the figure, the speed ratings associated with each speed limit were distinctly different from each other but the five ratings showed the same pattern of responses across the three speed limits. A 3 x 5 mixed design ANOVA showed that the ratings for the three speed limits were significantly different across the five speed ratings (self-reported speed, usual speed, eco speed, safe speed, & fun speed); [$F(2,144) = 121.38$, $p < .001$, $\eta_p^2 = .628$]. There was a significant difference between the five ratings [$F(4,576) = 25.26$, $p < .001$, $\eta_p^2 = .149$] but no interaction between speed limit and rating type [$F(8,576) = .494$, $p = .861$, $\eta_p^2 = .007$]. Bonferroni-adjusted pairwise comparisons indicated that ratings of fun speeds were significantly higher than all other speed ratings [*p*s < .001] while the lowest speed ratings were for eco speeds, which were significantly lower than all other speed ratings [*p*s < .05]. Mean ratings of safe speeds, usual speeds, and the self-reported speed for that day's drive was not significantly different [*p*s > .05].

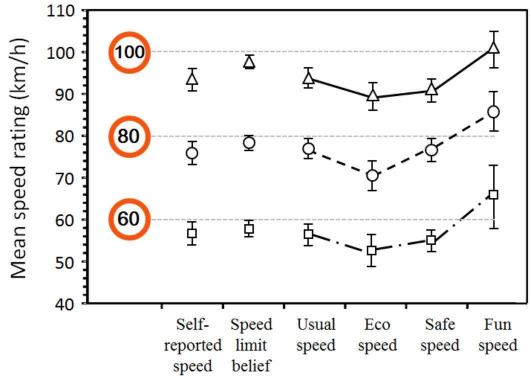

Figure 1. Comparison of mean speed ratings (km/h) for roads with three different speed limits. Lines show 95 % confidence intervals.

Experiment 2

Method

65 participants were recruited for this experiment. One participant requested that her data be withdrawn shortly after her completion. Of the 64 remaining participants (23 male, 41 female), ages ranged from 19 to 70 years of age (M = 39.1, SD =14.15) with all but two having a full New Zealand Driving license (exceptions held a restricted licence and a learner's license). Ethical approval for the recruitment and test protocols was received from the School of Psychology Research Ethics Committee at the University of Waikato.

Participants first completed a picture sort task in which they were asked to divide a randomly ordered stack of 34 A3 size photos of roads into piles so that their behaviour on the roads in one pile was the same and different to the roads in a different pile. The 34 photos used in this study were taken from high-definition video recorded from the driver's point of view on rural roads in the local region (and some participants volunteered that they were familiar with the roads in the photos). Following the picture sort the participants were then asked to give several ratings of how it would feel to be driving on the road in each photo including: how comfortable, how difficult, how monotonous (all on a scale of 1 to 5), what speed they would choose, what they thought was a safe speed, what they thought the speed limit was, and how safe they would feel (on a scale of 1 to 10).

Results

The number of times each photo was placed in a pile with each other photo was used to construct a similarity matrix for all 34 photos. The similarity data were used to form a two-dimensional multidimensional scaling solution (normalised raw stress = .056, dispersion accounted for = .944). The similarity data were then used in a hierarchical clustering analysis which was superimposed on the scaling solution in Figure 2 (after Riemersma 1988). The figure identifies six non-overlapping road clusters as follows: C1 = bridges, C2 = merge lanes and intersections, C3 = divided median roads, C4 = two lane straight roads, C5 = gentle horizontal curves, C6= severe curves. The figure also shows the mean speed choice and difficulty ratings for the six road clusters. A one-way Manova examining all six ratings (comfort, difficulty, monotony, speed choice, safe speed, and risk) indicated the six clusters were significantly different [Wilks' Lambda = .143; $F(30,33)$ = 27.053, $p < .001$, $\eta_p^2 = .961$] with the univariate Fs for each rating measure also showing significant differences between the clusters ($ps < .001$).

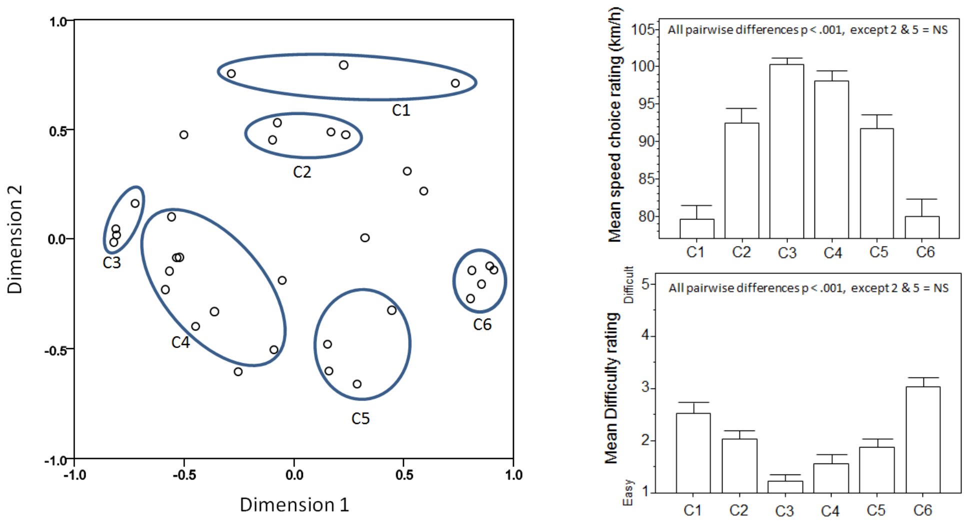

Figure 2. Multidimensional scaling of 34 road photos (left panel). Superimposed is the result of a cluster analysis of the same photos. The right panel shows the speed choice and difficulty ratings for the six road clusters. Lines show 95% confidence intervals.

As can be seen in the figure, the divided median roads (C3) and two lane straight roads (C4) were rated as the lowest in difficulty and the highest chosen speeds. A similar pattern for the clusters was seen across the other rating measures also. A series of multiple regression analyses predicting participants' speed choices for each cluster indicated that the best predictor was the participants' difficulty ratings (all $R^2 > .245$, *p*s < .05). Finally, the speed limit credibility (speed limit belief – speed choice) and safety margin (safe speed rating – speed choice) were calculated for each cluster. The analysis of pairwise differences between the clusters showed that speeds for C1 (bridges) and C6 (sharp curves) had the highest credibility scores and divided median roads the lowest credibility (*p*s < .001). The lowest safety margins, however, were seen for C5 (gentle curves, $p = .016$), followed by C4 (two lane straights, $p = .033$). In the case of C5, drivers actually chose faster mean speeds than what they considered to be safe speeds.

Discussion

There are many different reasons we drive cars, and the first study reported here shows that our motivations while we drive result in a wide range of different speed choices. The results are very similar to the findings reported in an earlier study (Oppenheim & Shinar, 2011) even though the two studies were quite different geographically; drivers chose the highest speeds when their primary motive was to have fun and the lowest speeds when their primary motive was to save money on fuel. The second study suggests that drivers form mental categories of familiar roads, as suggested by Riemersma (1988) and other investigators. This suggestion is supported by the finding that the road categories derived from the picture sort task predicted the speed choices gathered independently. Further, as suggested by Weller et al., (2008), perceived driving difficulty appears to be a key characteristic underlying these mental categories, significantly more so than risk of crashing. Taken together, the findings from these two studies suggest that drivers choose speeds on familiar roads, at least verbally, based on both their immediate trip purpose and mental categories (or road schemata) that they have formed with experience. The finding that the look and feel of roads can influence speed limit credibility suggests that we may be able to identify roads with poor safety margins based on drivers' perceptions and possibly even increase their safety by changing their appearance.

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Determining Fitness to Drive for Older and Cognitively Impaired Drivers - DriveSafe DriveAware a Touch Screen Test for Medical Practice

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Extended Abstract

Every year thousands of Australians are diagnosed with a medical condition that may impact ability to manage the cognitive aspects of driving, such as stroke, brain injury or dementia. Licensing authorities manage large numbers of drivers with potential cognitive impairment who wish to retain their ability to drive. Appropriately identifying 'at risk' drivers is a growing challenge. Responsibility for determining fitness to drive ultimately falls to the primary healthcare physician. General practitioners report concern about their role in assessing patient fitness to drive, including the impact of withdrawing driving on the patient's quality of life and the patient-doctor relationship. General practitioners frequently report a lack of objective, valid, and reliable tools for predicting driving ability to assist them in this role (Sims, Rouse-Watson, Schattner, Beveridge & Jones, 2012).

A standardised off and on-road driving assessment conducted a driver-trained occupational therapist is considered the gold standard for determining fitness to drive (Kay, Bundy, Clemson, & Jolly, 2008). This method of testing, however, is time consuming and costly, and access can be limited due to a shortage of specialist therapists. For more than 25 years, researchers have examined a variety of clinical tests to identify an off-road assessment that can accurately predict driving performance without taking drivers on the road. The computer version of DriveSafe DriveAware (DSDA) is one test that has shown sufficient sensitivity and specificity to predict on-road performance accurately (Kay, Bundy, Clemson, Cheal, & Glendenning, 2012). This test has been used by occupational therapists as part of a clinical assessment of fitness to drive for more than 20 years.

Computer administration of DSDA is limited to driver-trained occupational therapists because verbal responses need to be interpreted by trained professionals. The touch-screen version of the DSDA was therefore developed as a user-friendly test that would allow administration by general practitioners and other health professionals in clinical practice, without specialised training.

A prospective study was conducted to determine if touch-screen DSDA is a valid tool to use in determining if older and cognitively impaired patients are able to manage the cognitive aspects of driving, or if they required referral to a specialist driving services for further assessment.

Method

Touch-screen DSDA was administered to a convenience sample of 134 older (60 years +) and cognitively impaired (18 years +) drivers referred over a 7-month period to ten driver assessment and rehabilitation clinics across Australia (Sydney, Melbourne, Perth and Brisbane) and New Zealand (Wellington, Auckland and Hamilton). The purpose of the study was to examine the psychometric properties of the test and its predictive validity as compared to the criterion measure of a standardised occupational therapy on-road assessment. Sixteen driver-trained occupational therapists were involved in the study. They were blind to the results of touch-screen DSDA.

Measures

DriveSafe

The DriveSafe subtest consists of 10 images of a 4-way intersection. Each intersection includes a number of people and vehicles, ranging from 2 to 4 objects in total. These objects are presented for 4 seconds then disappear. For each of the 28 objects presented, the patient is prompted to recall 3 pieces of information: type of object, object location and direction of movement. One point is awarded for each correctly recalled piece of information, allowing a maximum score of 84. The subtest is self-administered with written and audio instructions and includes practice items.

DriveAware

The DriveAware subtest consists of 7 questions. The patient rates his or her perceived performance on the DriveSafe subtest in two self-administered questions. The remaining five questions are part of an interview that the administrator conducts at the conclusion of the test. The final question requires the administrator to rate their level of concern for the patient's fitness to drive, based on clinical or personal indicators. A discrepancy score is calculated for each item based on the difference between the patient's self-rating and actual performance on the DriveSafe subtest, along with the clinician's rating. A final score is generated by converting the discrepancy score (-2 to 2) into a final score via a 5-point ordinal scale. This results in a maximum total score of 17.

DriveSafe and DriveAware scores are combined to classify patient ability and awareness into the three categories: Pass, Fail and Further Testing.

On-road assessment – criterion measure

A standardised 60-minute on-road driving assessment was conducted in a dual controlled vehicle with a qualified driving instructor present to provide instruction and monitor safety. A driver-trained occupational therapist recorded driving performance against license authority standards. Performance Analysis of Driving Ability (P-Drive) was the standardised on-road assessment tool used to score driving ability using 25 actions observable during driving (Patomella, Tham, & Kottorp, 2006). These items are grouped in four headings; Maneuvers, Orientate, Follow Regulations and Attending and Acting. They are scored using a 4-point criterion referenced rating scale, from competent to incompetent performance. The outcome of the driving assessment was determined as 'pass', 'fail' or 'intervention' based on the definition used in standardisation of the computer version of the test (Kay, Bundy, & Clemson, 2009).

Statistical Analysis

Construct validity and internal reliability of the subtests were examined using a Rasch modelling technique (Bond & Fox, 2007) via Winsteps Version 3.72.2 (Lincre, 2014). Rasch modelling constructs a linear measure from ordinal scores by converting raw scores into logit scale scores and assessing goodness-of-fit for both items and participants along the same measure continuum. An item and participant map is generated in which items are arranged in order of difficulty and participants are arranged in order of competence. The analysis generates two pairs of goodness-of-fit statistics; infit and out-fit, expressed in two forms as mean square fit statistics (MnSq) and standardised fit statistics (ZStd). These statistics indicate how well data from each item and participant fit to the Rasch model with the assumption that easy items are easy for all participants and more competent participants perform better on all items. Items or participants with fit statistics outside the acceptable range should be considered for removal from the test.

The predictive validity of the DriveSafe DriveAware subtests was examined. Optimal lower and upper cut scores were determined using descriptive statistics. The lower cut score was set to identify those who were unsafe (i.e., Sensitivity and Positive Predictive Value) and minimising the proportion of drivers falsely categorised as unsafe (i.e., False Positive). The upper cut was set to identify those who were safe (i.e., Specificity and Negative Predictive Value) and minimising the proportion of drivers falsely categorised as safe (i.e., False Negative). Sensitivity and Specificity were calculated with a confidence interval (CI) of 95%.

Results

DriveSafe

Rasch analysis indicated that all DriveSafe subtest items have infit and outfit statistics within the acceptable range. The range of item difficulty was comparable to the range of participant ability, except for the most competent drivers. This is acceptable as the test is concerned with identify participants as ‘pass’ and not the level of competency within this category. All the statistics provided strong evidence for the unidimensionality and the construct validity of the subtest and indicated the test was sensitive enough to distinguish high and low performers.

DriveAware

The research version of the DriveAware subtest consisted of 8 items, however, 2 items were removed, as they did not perform. The remaining six items had acceptable infit and outfit statistics. All statistics indicated the subtest measured a unidimensional construct. As expected, the distribution of items in the item-person map confirmed that the DriveAware subtest should not be used as a stand-alone test. The hierarchy of items was conceptually logical and reflected a progression of awareness.

Predictive Validity of DriveSafe and DriveAware

To calculate predictive validity, the DriveSafe DriveAware subtests were used together to categorise participants who were predicted to fail an on-road assessment, those who were predicted to pass and those who required further testing to determine fitness to drive (such as referral to a driving clinic).

The optimal cutoff scores on the DriveSafe subtest were 57 and 72. The optimal cut-off scores on the DriveAware subtest were 10 and 13. The test identified unsafe drivers at the low cutoff score with Sensitivity of 91% (95% CI: 84 to 96) and 89% (95% CI: 82 to 97) for DriveSafe and DriveAware, respectively. The test identified safe drivers at the upper cutoff score with Specificity of 94% (95% CI: 87 to 99) and 91% (95% CI: 84 to 99) for DriveSafe and DriveAware, respectively.

The positive predictive value for the lower cutoff was 79% and 83% indicating that participants predicted to be unsafe had a high probability of being unsafe. The negative predictive values generated by the upper cutoff (65% and 57% respectively) indicated that participants predicted to be safe had a slightly high probability of being safe.

The predictive validity results provide the empirical evidence for DriveSafe DriveAware test with Specificity of 86% and Sensitivity of 91%, Positive Predictive Value of 83%, Negative Predictive Value of 92% and the overall Accuracy of Classification of 88%.

Conclusion

The results of this study present evidence that supports the clinical utility of touch-screen DSDA in predicting with substantial accuracy, which patients with a cognitive impairment require an on-road assessment. People who are not a good candidate for an on-road assessment (i.e., those who will likely 'fail') can be advised not to drive and can be redirected to use their time and monetary resources in other ways. The research evidence supports the conclusion that the test has retained the strong psychometric qualities of the computer version of the test, including internal consistency, predictive validity and ability to classify drivers into 'pass', 'fail' and 'further testing' categories.

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Longitudinal patterns in older drivers' speeding behaviour

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Abstract

Introduction

Older drivers are at increased risk of involvement in casualty crashes and injury compared to younger drivers (BITRE, 2014; Rakotonirainy, Steinhardt, Delhomme, Darvell, & Schramm, 2012). Speeding increases crash risk and resulting injury severity (Aarts & van Schagen, 2006; Kloeden, McLean, Moore, & Ponte, 1997; Kloeden, Ponte, & McLean, 2001; Williams, Kyrychenko, & Retting, 2006). However, there is little objective evidence about older drivers' speeding or factors that may influence this behaviour. This study investigated the prevalence and nature of speeding over a year, and whether cognitive and visual function, age, gender or driving history influenced speeding.

Methods

In-vehicle monitoring systems recorded driving data for up to 12 months for 182 participants aged 75-94 years (median 80). Volunteer participants were the control group from a Randomised Controlled Study (RCT) examining an educational safety program (Keay et al., 2013).

Driving speed was estimated in approximately one-second intervals using Global Positioning System (GPS) location. Speed limit data was based on a service-provider database developed through on-road mapping of the road network. Speed events were defined as driving 1km/h or more, with 3% tolerance, above a single speed limit, averaged over 30 seconds.

As a previous cross-sectional analysis examining this study cohort found increased age and decreased function were significantly associated with reduced mileage (Coxon et al., 2015), it was important to examine speed events as a single outcome measure as well as a rate by adjusting for distance driven. As speed events were over-dispersed, negative binomial, repeated measures regression were conducted to determine factors that may predict involvement in speed events. A second series of regression modelling examined predictors of involvement in speed events with distance driven applied as a measure of exposure. As there were statistical associations between the predictors, they were not considered suitable for

testing within a multivariate model. Model fit of significant univariate models were compared based on the quasi-likelihood under the independence model criterion (QIC), and presented in the results in order of best model fit.

Candidate predictive factors included four measures of function collected at baseline and 12 months, including contrast sensitivity, Trails Making Test Part B (TMT B), DriveSafe and DriveAware. TMT B assessed participants' visual scanning and executive function (Betz & Fisher, 2009; Bowie & Harvey, 2006). TMT B results were measured in seconds, with longer time to complete indicating lower function. Research indicates TMT B is predictive of crash involvement (Emerson et al., 2012; Staplin, Gish, & Sifrit, 2014; Stutts, Stewart, & Martell, 1998) and driving performance (Classen, Wang, Crizzle, Winter, & Lanford, 2013). DriveSafe assessed participants' visual attention to the driving environment through viewing and recalling components from driving scenes, with a higher score indicating better performance (Kay, Bundy, & Clemson, 2009a). DriveAware assessed participants' awareness of their driving ability and functional limitations through driving performance questions, with a higher score indicating lower awareness (Kay et al., 2009a; Kay, Bundy, & Clemson, 2009b). DriveSafe and DriveAware used together have been validated as predictive of driving performance for people with cognitive impairment against an on-road test (Kay et al., 2009a).

The baseline scores for these functional measures were included in the regression models. In addition, the difference in scores between baseline and 12 months were calculated to determine change in function. Binary values of decline or no decline were generated for change in function for each of the four measures based on pre-determined, clinically meaningful thresholds. The impact of decline in function was modelled, adjusting for baseline scores.

In addition, four other candidate predictive factors were examined: involvement in crashes as a driver, receiving a traffic fine in the past year, age and gender. These were self-reported at baseline and 12 months. These were summed and divided by two to calculate an annual average. Demographic factors were collected at baseline.

Results

Descriptive analysis found of those participants with reliable vehicle monitoring data (97% or 177/182), almost all (99%, 176/177) were involved in speed events. While the majority of speed events (92%, 130,581/142,583) involved driving an average 1-9km/h above the speed limit, 3% (3806/142,583) involved speeding an average 30km/h or more above the speed limit, and the majority (78%, 111,748/142,583) of events occurred in areas with a 50-60km/h speed limit, where there tends to be increased pedestrian activity and traffic.

Negative binomial univariate modelling found speed events decreased by approximately 7% with every year increase in age (IRR=0.93, $p<0.001$, 95% CI=0.89-0.96). Univariate modelling found speed events decreased by approximately 11% for every decrease of 10 in DriveSafe score adjusted for DriveAware (IRR=0.89, $p=0.02$, 95% CI=0.080-0.999), and speed events decreased by approximately 9% with every 20 second increase in time to complete TMT B (IRR=0.91, $p<0.001$, 95% CI=0.87-0.95).

When speed events were examined as a rate per km travelled, these associations were not evident. The distance driven decreased by approximately 0.45km with every week during the year of monitoring (Coefficient = -0.45, p<0.001, 95% CI = -0.66 to -0.24).

Discussion

Speeding events were prevalent in this older group of drivers. Most events involved low range speeding and occurred in lower speed zones, though concerningly some were significantly above the speed limit. The findings indicate older drivers with lower function are less likely to be involved in speed events over a 12 month period of monitoring. However, as age and measures of function were not significant when distance driven was taken into account, it appears the mechanism by which speed event involvement is reduced is through driving less.

A previous analysis of this cohort found age and function were associated with reduced mileage (Coxon et al., 2015). In addition, this analysis found driving exposure reduced over the year of monitoring.

Of participants, 16-31% were found to experience a clinically meaningful decline in cognitive or visual function during the 12 months. However, changes in function adjusting for baseline function scores were not predictive of a change in speed events with or without applying distance as an exposure measure. A longer period of follow up may be required to determine if larger changes in function would influence speeding behaviour. Gender, and average annual crashes or citations were also not predictive of a change in speed events with or without distance applied.

Conclusion

To the authors' knowledge, this is the first study to investigate older drivers' speeding using longitudinal, objective data, or examining the relationship between lower function and driving behaviour and speeding. With a growing population of older drivers, these results are important for developing policy to address speeding behaviour of older drivers to reduce the incidence of crashes and resulting casualties, as well as informing further research. Low range speeding was prevalent for older drivers. Increased age and lower levels of function were associated with a reduction in speed events. These findings indicate drivers may be adjusting their behaviour to cater for reduced function, and a key component to reducing older driver's involvement in speed events may be to reduce distance driven.

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Preliminary investigation of the impact of roadside oral fluid testing and increased penalties on illicit drug-driver fatalities in Western Australia

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Abstract

Background

Illicit drugs such as cannabis and methamphetamine are well-known causes of driver impairment and significant risk factors for crashing and personal injury. In Western Australia, recent research showed that 23% of drivers fatally injured during the period 2000 – 2012 tested positive for one or more illicit substances (Palamara et al. 2014). To combat illicit drug driving in Western Australia, a number of initiatives have been implemented in in recent years, namely the introduction of Roadside Oral Fluid Testing (ROFT) (October 2007) and an increase in penalties for illicit drug driving (Section 64AC offence) (October 2011). From the perspective of Deterrence Theory, these countermeasures respectively aim to increase drivers' perception of the likelihood of being detected for drug driving and the judged severity of punishment for doing so. To date there has been no investigation of the effectiveness of ROFT on the incidence of illicit drug related crashes in Western Australia or where introduced elsewhere. Similarly, there is a dearth of studies investigating the impact of increased penalties for drug driving. Consequently, it is of interest to model and quantify, where possible, the impact of drug-driving countermeasures such as those implemented in WA on illicit drug driver behaviours/outcomes.

Aims

To undertake a preliminary investigation of the impact of the WA illicit drug driving countermeasures on illicit drug related driver fatalities from January 2005 to November 2012.

Methods

The de-identified linked crash and toxicology records of WA motorcar drivers and motorcycle riders fatally injured during the period 2000 – 2012 were retrieved from WA Police. Each fatality was classified according to the presence or absence of both illicit (e.g., alcohol, caffeine, prescription medications etc.) and illicit substances (e.g., cannabis, methamphetamine, ecstasy, heroin, cocaine) by the ChemCentre, WA (formerly known as the Chemistry Centre) on behalf of the Coroner.

The introduction of increased penalties and changes in enforcement practices for drug driving over time and at varying times represent a quasi-experimental designs (because of their non-random assignment). The availability of retrospective administrative data on various outcomes related to drug driving behaviours prior to and following the introduction of these interventions means that time series of (1) the monthly proportion and (2) the monthly rate (per 100,000 motor vehicle licenses (MDL) issued in WA) of fatally injured drivers and riders testing positive for an illicit substance can be constructed and analysed as interrupted time series. Interrupted time series is regarded as the strongest quasi-experimental design for the evaluation of longitudinal effects of time specific interventions (Wagner et al. 2002) such as drug driving countermeasures.

Statistical analysis of the interrupted time series data for drug driving outcomes impact of the penalty and enforcement changes was undertaken using *segmented regression analysis* (see Wagner

et al. 2002). The segmented regression technique has been employed by other investigators to address a range of health (e.g., Wagner et al. 2002) and road safety outcomes including statutory penalties for drink driving (e.g., Briscoe, 2004; Nagata et al. 2008). This is a simple yet effective approach of analysing the potential effects of single or multiple interventions on a time series by modelling the time series and the interventions as a single multiple linear regression to statistically determine the impact of each intervention on the immediate and longer term outcomes of interest (Wagner et al. 2002). Changes, either immediate or longer term, in (1) the monthly proportion and (2) the monthly rate of fatally injured drivers/riders testing positive that coincided with the two WA drug driving countermeasures of interest were investigated in this study.

Results

Neither *ROTF* (October 2007) nor *increased penalties* (October 2011) was found to be associated with a significant change, either immediate or ongoing, in the monthly proportion of fatally injured drivers and riders testing positive for an illicit substance (*p*-values of potential changes ranged from 0.1340 to 0.8688).

In terms of the monthly rate of fatally injured drivers and riders testing positive, only *ROTF* (October 2007) was found to be significantly associated with an ongoing monthly reduction of 0.0024 fatalities per 100,000 MDL issued (*p*-value = 0.0249) (Table 1).

Table 1. Segmented Regression of the monthly rate (per 100,000 MDL) of fatally injured drivers/riders testing positive for an illicit substance; Western Australia 2000-2012 (adjusted for potential seasonal effects (by month))

	Coefficient	Standard Error	t	Significance
(Constant)	0.0709	0.0317	2.2348	0.0269
Trend – prior to interventions	0.0006	0.0004	1.7075	0.0897
Immediate Change – ROFT	-0.0004	0.0344	-0.0111	0.9912
Change in trend – after ROFT	-0.0024	0.0011	-2.2649	0.0249
Immediate change – Increased Penalties	0.0312	0.0613	0.5089	0.6115
Change in trend – after Increased Penalties	-0.0002	0.0065	-0.0365	0.9709

While the long term change in trend after the introduction of *ROFT* was significant, one concern was that the ANOVA of this initial model was not statistically significant (*p*-value = 0.4306). Neither *increased penalties* nor the seasonal adjustments were found to be associated with a significant change in the monthly rate; consequently they were removed from the segmented regression to further streamline the model. The streamlined model, with the ANOVA now significant (*p*-value = 0.0321), had found the entire study period after the introduction of *ROFT* (October 2007 – November 2012) to have sustained an ongoing monthly reduction of 0.0019 fatalities per 100,000 MDL issued (*p*-value = 0.0115) (Table 2).

Table 2. Streamlined Segmented Regression of the monthly rate (per 100,000 MDL) of fatally injured drivers/riders testing positive for illicit drugs; Western Australia 2000-2012 (adjustment for seasonal effects and Intervention 2 (increased penalties) removed from the model)

	Coefficient	Standard Error	t	Significance
(Constant)	0.1133	0.0195	5.7973	0.0000
Trend – prior to interventions	0.0007	0.0004	1.8204	0.0706
Immediate Change – ROFT	-0.0119	0.0308	-0.3855	0.7004
Change in trend – after ROFT	-0.0019	0.0008	-2.5584	0.0115

Discussion/Conclusion

Notwithstanding limitations which relate to (1) the outcome data selected for analysis, (2) the timing of the evaluation and length of follow-up, (3) the absence of additional information related to the deterrence of driver behaviour, and (4) identifying and adjusting for other possible confounding factors, the findings provide preliminary evidence of the positive impact of *ROFT* on illicit drug driving fatalities and the limited impact of more severe penalties on illicit drug driving behaviour in the absence of a corresponding and supportive increase in the level of enforcement (either actual or perceived).

To overcome the identified limitations of the current research, future research should (1) be conducted using a lengthier period of follow up for crashes and drug driving offences; (2) use additional source of "outcome" data including *ROTF* test results and driver offence/conviction data for drug driving; (3) use linked crash, offence and licensing history data to investigate the impact of penalty changes on recidivist behaviour; and (4) adjust for monthly levels of *ROTF* for illicit drug enforcement activity.

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Enhancing offender programs to address recidivism

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Abstract

Legislation and enforcement systems are recognised effective mechanisms to curb illegal driving behaviours, particularly amongst young offenders. Evidence suggests that when applied together with behavioural and educational programs, significant gains can be achieved toward reducing the prevalence and recidivism of these behaviours. A review of best practice evidence and comparison with two examples of educational programs currently implemented in Victoria was undertaken, in order to better understand the potential benefits of such programs. These programs are built on restorative justice principles, employ a cognitive behavioural approach designed to support behaviour change through a process of education, reflection and prevention, and are offered as part of either a sentencing option (for older and recidivist offenders) or early intervention (targeted at youths). The comparisons focused on key aspects of delivery, content, style, structure, and therapeutic approaches. The findings suggest that overall these programs meet best practice standards and principles and therefore have the potential to make a significant contribution to the reduction of driving offence recidivism. Implications of the findings are discussed in terms of effectiveness of components, feasibility, practical implications and potential further enhancements to offender programs.

Introduction

Our overall road safety system is undermined when individual road users commit traffic offences, engaging in illegal driving behaviours that have been deemed unsafe and associated with increased crash risk. Legislation and enforcement systems are recognized as an effective means to curb illegal driving behaviours. Sanctions for offenders consisting of varying punishments, including accumulation of demerit points and fines, driver's licence suspensions or disqualification, confiscation or immobilisation of automobiles, and jail time. These interventions are aimed at reducing driver recidivism rates through punishing offending drivers (Mann, Leigh, Vingilis, de Genova et al., 1983). Punishment-based interventions have traditionally been the primary mode of deterrence, indeed, such legislation, allowing for the testing and penalizing of drivers who are apprehended for engaging in illegal behaviours, has been in operation across Australia for many years.

While current enforcement systems continue to play a key role in deterring illegal driving behaviour, research identifies the importance of addressing driver attitudes in order to achieve positive driver behaviour change (Iverson, 2002; Ulleberg & Rundmo, 2003). Indeed, there is increased recognition that a collaborative approach incorporating rehabilitation and educative programs into existing enforcement sanction regimes, can achieve greater gains in reducing the prevalence and recidivism of traffic offender behaviours. However, there is also very little evidence attesting to the effectiveness of such programs, particularly an examination of best practice elements of these programs.

This study was undertaken to explore current international best-practice principles in the field of driver education and offender programs and compared these findings with two well-known and established offender programs conducted in Melbourne, Victoria. The overall aim of the project was to provide recommendations regarding program enhancement based on the best practice principle findings particularly with regard to key messages, program content and delivery. This paper outlines some of the key findings and implications of the research.

Methodology

This project involved two phases including i) a review of the literature pertaining to the best practice application of offender programs as an education and rehabilitation countermeasure, particularly in relation to traffic offending behaviour and recidivism, and ii) a comparison of best practice principles with two well-established comparable traffic offender programs run in Melbourne, Victoria.

Relevant published and grey literature were sourced to identify existing offender programs, evaluations of programs (if available), and the general literature on road safety education, rehabilitation and offender programs, mandatory treatment, intervention, etc. An extensive range of search engines and databases was utilised to source literature and included: Embase, SafetyLit, ScienceDirect, Ingentaconnect, Tandfonline, CRCNetbase, and other relevant databases including PsychInfo, Medline, Cochrane Library and Scopus. Key words included: driver education, novice/young driver, road safety education programs, traffic offender courses, mandatory treatment, recidivism, juvenile offenders, habitual offenders, rehabilitation, intervention, evaluation. There were no exclusion criteria.

The comparison was undertaken by reviewing key principles and components of existing Victorian programs with the findings from the literature search.

Results and Discussion

The role of traffic offender programs

Rehabilitation approaches initially evolved as alternatives to punishment–based interventions, and are based on the rationale that offenders require supportive treatment environments to assist them in changing their undesired behaviours (Mann et al., 1983). Within road safety, the focus of these rehabilitation type programs is typically on providing drivers with the knowledge, skills and strategies to avoid further high risk driving behaviours.

Road safety rehabilitation programs, such as Driver Improvement Programs (DIPs), are widely applied in the United States as a countermeasure to address traffic violations, convictions and crashes experienced by drivers through helping them correct their potentially dangerous driving behaviours (Zhang, Gkritza, Keren, Nambisan et al., 2011). Analyses of DIPs with regard to crashes and violations have concluded that generally the programs result in reductions in violations (Lund & Williams, 1985; Masten & Peck, 2004), with a less pronounced reduction in crashes (Ker et al. 2005). However, in their analysis of the Iowa DIP program, Zhang et al. (2011) found only two percent participant crash involvement in the 13 to 18 month post-program period but that most drivers were reconvicted of a new offence within 90 days of completing the course. Additionally, the study found that DIPs lowered the probability of both male and female drivers incurring future convictions compared to drivers who had not completed the course. Masten and Peck (2004) found that the offender intervention programs included in their study resulted in traffic offence reduction for between

6 months and 2 years, with the longer and more comprehensive programs having the longest effect.

Generally it is noted that there is a lack of strong evidence associated with the effectiveness of sanctions, education, and intervention programs when evaluated independently, with very few studies reporting strong positive effects. One of the key issues with evaluations of driver offender programs is that the effectiveness of the program has been evaluated against a reduction in participants' future crash rates (Wåhlberg, 2011). This poses difficulties due to the low crash rate frequencies and hence associated analytical statistical power, very large sample sizes are required to support meaningful analysis. While deterrent effects generally increase with the severity of the punishment (Yu, 1994), in DeYoung's (1997) evaluation of the effectiveness of treatments in reducing drink driving recidivism rates it was shown that jail terms were ineffective, even amongst first time offenders. In contrast, the combination of license restrictions and first offender programs was associated with the lowest recidivism rates compared with other sanctions evaluated. These findings were also consistent for second time offender drivers. The study found that treatment programs were more effective than licence suspension alone (DeYoung, 1997).

Evaluations of studies based on behavioural change and program content recall have been shown to have more positive effects however, there are drawbacks with behaviour change and recall being more weakly associated with crashes. In addition, content recall is not necessarily a precursor for actual behaviour change, simply because there is not always automatic transfer from knowledge to behaviour. While achieving long-term behaviour change would be a desired outcome for most traffic offender countermeasures, it is not necessarily possible; therefore the intention of many programs is to educate and inform participants of the possible risks and consequences associated with adoption of risky driving behaviours and to take responsibility for their choices and actions.

Previous research conducted in Victoria found that education type programs do play a role in shifting participant's motivation to change (Sheehan, 2005). Short education programs, have been found to be a cost effect means of intervention. These programs are particularly cost effective when implemented as a user pays program and can provide a positive complement to other forms of sanctions, such as fines and licence suspensions (Wundersitz & Hutchinson, 2006). Some successful programs have utilised a combination of both education and punishment techniques and evaluations have shown that these programs are associated with a reduction in driving offences; however no programs have been associated with reductions in crash rates (Wåhlberg, 2011).

The Driver Intervention Program (DIP), operating in South Australia is mandated for any young learner or probationary driver (under the age of 25) who has had their licence disqualified for any offence, including first offences. Since its introduction the program has undergone two evaluations, the first in 1996 (Drummond, 1996) and the second in 2006 (Wundersitz & Hutchinson, 2006), with the most recent evaluation estimating conservatively that DIP programs may result in a 5% crash reduction. Further, given the low costs associated with delivering these programs, the benefit-cost ratios would be substantial, therefore justifying the costs of delivering these programs

Best Practice Traffic Offender Programs

While it is acknowledged that there are challenges in measuring the effectiveness of behavioural programs, all literature providing evaluative research on program effectiveness including evaluations of program components and outcome measures was examined to determine what is 'best-practice'. Overall, the findings of the review suggested that there are six key considerations that are present in offender programs that are considered 'best-practice'. These are discussed below.

Theoretically based

Much of the literature assessing the effectiveness of community-based programs focuses on interventions based on Cognitive Behavioural Therapy (CBT). The overwhelming evidence shows that these treatment approaches are the best approaches for antisocial youth and result in positive outcomes to prevent or reduce antisocial behaviour (Izzo & Ross, 1990; Lipsey et al., 2001; Armelius & Andreassen, 2007).

Izzo and Ross (1990) found that interventions based on a theoretical principle or models were, on average, 5 times more effective in reducing recidivism than those that were not. In addition, interventions that included a cognitive component (problem solving, negotiation and interpersonal skills training, rational emotive therapy, role playing and modelling, and cognitive behaviour modification) were more than twice as effective as those that did not. Wilson and colleagues (Wilson, Bouffard, & Mackenzie, 2005) examined 20 studies of group-oriented CBT programs for juvenile offenders, including Moral Reconation Therapy and Reasoning and Rehabilitation. They concluded that representative CBT programmes reduced re-offending by 20-30 percent compared to control groups. In addition, Pearson, Lipton, Cleland et al. (2002) reviewed 69 research studies of behavioural (e.g. contingency contracting, token economy) and CBT programmes. CBT programmes were more effective than the behavioural ones in reducing re-offending, with a mean reduction in recidivism of about 30 percent for treated groups.

One of the major contributions of Restorative Justice to the criminal justice system is its incorporation of emotional dimensions into the understanding of offender behaviour. Evolving research from within this field by Harris, Walgrave and Braithwaite (2004) questions the common reliance on, and effectiveness of, promoting disapproval and inducing the emotion of shame for offenders in attempts to encourage positive behavioural changes. To the contrary they highlight the importance of programs that treat offenders in a respectful manner to promote their development of empathy. The development of empathy is recognised for its role in promoting remorse and reconciliation which they view as the key to achieving successful, positive, law-abiding behaviour change (Harris et al., 2004).

Target group characteristics

The findings of the review also revealed that more specialised programs that are linked to the characteristics and risk factors of offenders being targeted by the intervention, are more effective than traditional programs that incorporated a 'one-size-fits-all' approach across all traffic offender groups. Some examples of targeted programs include:

- General safer driving practices: Crash and injury prevention programs generally focus on addressing road rules, safe driving, substance abuse, law obeisance, defensive driving, and emotions and attitudes towards dangerous driving practices.

- Drugs and Alcohol: Programs that deal with potentially addictive behaviours such as drugs and alcohol should note that the complexities of these behaviours play a key role in program design and development, with participants requiring targeted treatment due to underlying substance abuse issues, in conjunction with addressing high risk driving behaviours (Marques et al., 2000).

- Recidivist prevention: These programs generally follow a structure of problem recognition, definition, correction and resolution. In their review of driver offender programs, (McKnight & Tippetts, 1997) found that programs aimed at recidivism prevention resulted in significantly fewer accidents and violations during the following year. Recidivist programs are ideally structured when they can target key demographic variables (Sheehan et al., 2005). Shorter programs are suited to address the issues associated with first time offenders who have engaged in low range driving offences, while longer, more complex, treatment based programs are better suited to treating habitual recidivist drivers.

- Age group: Programs targeted at specific age groups are more effective in addressing relevant behavioural and motivational issues. Education programs can be targeted at various age groups including pre-driving populations, novice drivers and young drivers. Programs targeted towards traffic offenders typically do not have any age limits; however participants are often in the 15-25 years age group. Over representation of younger drivers in these programs is partially attributed to their increased likelihood of engaging in risky driving, and the relatively high rate of driving offences amongst younger drivers. There is also some suggestion that there is an increased rate of referral to these programs for young drivers by magistrates. This is in recognition that there is a greater chance of successful intervention for young drivers as their behaviour may be more a reflection of immaturity and lack of insight and knowledge rather than entrenched or habitual.

Offender programs are typically targeted towards repeat offenders, who exhibit higher risk characteristics. In recent times there is a growing recognition of the advantages of adopting preventative strategies such as driver education programs that target young drivers and first time offenders.

Key messages

Key message play an important role in delivering the desired information within a group setting and need to be of high quality and credible. Young people are constantly exposed to messages from various media and have become effective critiques of poorly presented messages. Messages should be tailored to support the facilitator/participant connection to maximise persuasiveness for promoting the desired participant behaviour change (Wolf, 2001). In group facilitation key messages are commonly confused with the re-stating of goals, goals which are not necessarily shared by the target audience to the same degree as the organisation promoting them. The role of key messages are to support the attainment of the goals (Wolf, 2001) and an important aspect of facilitating successful behaviour change is to actively listen to the participants and hear firsthand what obstacles to change they are faced with.

Another primary role of a key message is to build rapport with, and engage the support of, the audience. It is important that messages are designed to align with a person’s current belief system as attempts to force a change in beliefs will typically meet with resistance and therefore failure (Wolf, 2001).

Goals need to be well defined and obtainable; participants may need guidance to break goals down into smaller achievable steps that will lead them toward their overall goal. There is evidence that successful conveyance of one crucial key message may have a greater impact than partial conveyance of several messages for some difficult or resistant client groups.

Participant engagement

The evidence shows that there has been a shift from the traditional lecture type education model to a more client interactive model and that interactive models are more effective than traditional models. This focus on increased engagement has been facilitated through the incorporation of a range of learning mediums and choice of media needs to consider the target audience (Sheehan et al., 2005). For example, interactive, dynamic and highly simulating interfaces are appropriate to engage younger audiences, given their high use of advanced technology. Widely used interfaces such as Google, Facebook and Twitter offer a relatively low cost ability to target a wide audience (national and international) within a short time-frame.

Wells-Parker and Bangert-Drowns (1995) found that programs which focused on lifestyle change strategies resulted in an overall positive effect on knowledge and attitudes towards drink driving behaviours. The findings of the current study found that most effective rehabilitation programs incorporate a combination of intervention methods including education, lifestyle change, and probationary contact and supervision.

Optimal program content

The appropriate degree of structure within a program is somewhat difficult to define and measure. The main argument presented for permitting program flexibility is that it allows a facilitator to tailor sessions to suit individual client groups; however care must be taken that the overall aims and objectives of the program are not undermined. Advantages of developing structured program content include: maintaining inter-facilitator consistency; ensuring the theoretical based objectives of the course content are maintained; and, presenting a sterner atmosphere for participants who have committed offences (Sheehan et al., 2005). In addition, the more flexibility permitted within course content the more challenging it is to conduct robust empirical evaluations.

Program facilitators and presenters

It is important that the programs are conducted by professional facilitators, trained in counselling, who are well versed in identifying and accommodating valuable adult learning factors (Sheehan et al., 2005). The following qualifications have been recommended for facilitators of driver education programs for recidivist speeding: 21years or older, adult education/social science qualification, hold a current drivers licence (3 yrs +), no licence suspensions/disqualifications, pass a police check (Styles et al., 2009).

National based programs

The implementation of state or nationally based programs across Australia would promote the delivery of a consistent approach to traffic offender education programs. Comparable program delivery would further support the conduct of empirical evaluations and the development of specialised programs to target the various traffic offender profiles.

Comparison of best practice findings with existing offender programs

In this research phase two short, education based traffic offender programs, designed and facilitated by the Road Trauma Support Services Victoria (RTSSV) were reviewed for comparison with the results of the best practice review findings.

The RTSSV have developed traffic offender education programs such as the Road Trauma Awareness Seminar (RTAS) and the more recently developed Drive To Learn program (DTL). The RTAS, in operation since 2004, is conducted in conjunction with referrals from the Victorian Magistrates' Court and targets first time or recidivist traffic offenders across all age groups. The more recently developed DTL program (2013) is conducted in conjunction with the Dandenong Magistrates' Court and targets young offenders aged up to 17 years, in their pre-licensing phase, who have been charged with (or are facing) charges relating to traffic offences.

These programs are short, non-treatment based offender programs designed to reduce road trauma through traffic offender education that promotes the adoption of safer driving attitudes and behaviours and reduces recidivism. More specifically the programs are designed to: confront and evaluate participants' current road user belief systems; assist participants in identifying and managing precursors to offending; provide peer discussion and problem solving; provide reality based learning using volunteer/emergency service worker presentations; develop a commitment from driving offenders to engage in the official licensing process and traffic legislation; reduce the risk of further traffic offending and further involvement in the criminal justice process; and, reduce the likelihood of participants causing or being involved in road trauma through developing an understanding about the impact of their behaviour on themselves and the wider community.

Theoretical basis

The RTAS and DTL programs are based on restorative justice principles and three psychological models: Narrative Discourse (White & Epston, 1990), Experiential Learning (Kolb et al., 1971), and Cognitive Behavioural Intervention (Goldfried & Davison, 1994). The programs are designed to encourage participants to change their illegal high risk driving behaviour through a process of education, reflection and prevention (RTSSV, 2010b).

Narrative Discourse: The RTAS and DTL uses accounts of events and employs the concept of volunteer speakers re-tell their own personal accounts of road trauma. This component plays a key role in i) providing a real world understanding of the consequences of road trauma, and ii) provides a forum for volunteers to re-direct their personal experiences of road trauma towards a constructive objective.

Experiential Learning: The RTAS and DTL promote active involvement of participants in an event, critically reflecting on their involvement, identifying the important and productive elements of their involvement, and then utilising this information to perform the same or similar activities in the future. During the programs participants are guided through a process of examining their own actions that led to their infringement, to recall the event in a frank manner (no excuses or legitimisation) and to explore how they could deal with this situation in a more productive/safe and legal manner in the future.

Cognitive-Behavioural Intervention: The programs use this powerful technique to assist participants with learning to express what they believe, need and feel. During the programs, participants are encouraged to move from a role of passive victim to that of active and capable agents of change with the ability to make the decisions necessary to change their attitudes and behaviours. Goldfried and Davidson suggest that cognitive-behavioural interventions are more suitable in prevention programs with persons at risk compared to other therapies and have been found to have enduring effects.

Program delivery

The RTAS targets first time or recidivist traffic offenders of any age, however the participants are typically young males (<26 years), convicted of a ‘hoon’ type offence, and referred via the Magistrates’ Court, solicitors, or through self-referral. The seminars are conducted on a regular basis across the Melbourne metropolitan area as well as several regional and rural centres across Victoria. Currently approximately 1,200 participants attend the program per year with around 10 participants per program. The target group for the DTL program is youth (predominantly male) aged up to 17 years (pre-licensing) who have been charged with (or are facing) a traffic offence. Their offences commonly include theft of motor car, driving in a dangerous manner, reckless conduct endangering life/causing injury, unlicensed and learner driver offences. The program is currently conducted in the Dandenong Region where it was developed, however the RTSSV plan to extend this coverage to other metropolitan and regional areas. Referral to attend the DTL can be self-initiated, through a representing lawyer or directly from a magistrate. With Magistrate referrals sentencing can be deferred allowing time for attendance at the DTL program and completion of the program can then be taken into consideration for final sentencing.

The RTAS and DTL are user-pay programs, the RTAS is a 2.5 hour program and the DTL is 3 hours in duration. A similar format is employed for both programs with flexibility for facilitators to tailor the program to suit the target audience and offender profiles, while still adhering to the overall format and philosophy of the programs. The programs are designed to be interactive with a requirement of active participation in order to obtain a certificate of attendance to present at court.

The facilitators (Educators) are employed by the RTSSV and are typically from a social science/counselling background. Key prerequisites for all facilitators are: relevant experience working in road trauma-related fields; qualifications in relevant fields such as adult education or health; and, experience working with offender/group facilitation. The Educators undergo extensive and ongoing training processes and attend regular team meetings and have regular communication regarding program modifications (RTSSV, 2004).

A volunteer presenter attends each program session, the volunteer can be an Emergency Services representative or a community volunteer who has personally experienced road trauma (themselves or family members). The community presenters have typically been clients of trauma counselling at the RTSSV however, it is recommended that they wait at least 2 years post trauma before taking on this role. Presenters are required to attend a training program facilitated by the RTSSV. The volunteer presenters’ role in the programs is to give a 15-20 minute presentation based on their personal experience of road trauma; they do not play a role in facilitating the seminars.

Summary of comparison of RTAS and DTL with best practice findings

The characteristics and features of the RTAS and DTL programs were compared with best practice findings of comparable programs. These findings are detailed in Clark & Edquist (20120)0 and Oxley, O'Hern & Clark (2014) and summarised here. The results suggested that, overall, the RTAS and DTL programs align well with overall youth justice system principles and therapeutic approaches. The programs are based on restorative justice and diversion from entering the system. The programs are also community-based and include CBT. Further, the program implementation, content, structure and staffing was compatible with best practice approaches. They target specified age groups, particularly young drivers, and recognise heterogeneity of groups.

Recommendations and Conclusions

This study explored the available literature pertaining to best practice principles relating to short, non-treatment based offender programs which aim to bring about attitude and behavioural change, and reduce recidivism and hence road trauma. The findings showed that existing programs generally meet good practice requirements. However, there were some aspects of the programs that could be enhanced, and a suite of recommendations for consideration are provided. These include recommendations for additions to therapeutic approaches, target group considerations, additions to program content and key messages, as well as recommendations to ensure that appropriate and measureable variables are collected and available for robust evaluation of the program in the immediate and long-term future.

Driver offender programs are designed to complement existing enforcement practices. When viewed as an educative program aimed at providing participants with insight into the risks associated with these high risk driving behaviours, such as facing further sanctions or being involved in a serious injury or fatal crash, these programs have been found to be cost effective. They provide a low cost user pays option to support participant exploration of the risks associated with illegal driving behaviour, the potential consequences for themselves, families and other road users and to explore alternative positive driving practices.

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Enhancing the Evaluation of Road Safety Communication Programs: Developing an Evaluation Strategy

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Abstract

Motor Accident Commission (MAC) funds and delivers the South Australia (SA) Government's road safety communication programs. MAC is committed to improving the evaluation of its road safety communication programs, as a means of ensuring the value of the program spend and evolving understanding of, and application of, the factors of success to maximise road safety outcomes. MAC has developed a practical Evaluation Strategy for road safety communications based on a review of international research and best practice. This paper describes the Evaluation Strategy and its development to assist other jurisdictions in undertaking evidence-based and practical approaches to determine the efficacy of road safety communication programs. The Evaluation Strategy identifies a framework and structure for the program development-implementation-improvement cycle. Rigorous and comprehensive evaluation methods can impose significant costs. The MAC Evaluation Strategy therefore provides Tiered Evaluation Options which allow the level of evaluation to be determined depending on budget and the size, originality, and type of program being considered. Three types of communication programs are identified, and five tiers of outcome evaluation options as well as two process evaluation options are described for each type of communication program. The Strategy goes beyond common evaluation processes by adding the potential for evaluations based on dedicated observations of relevant behaviours on-road and provides for a more rigorous assessment of the relationship between campaigns and changes in crashes and casualties.

Introduction

Road safety communication programs continue to be widely implemented because of their potential benefits for road safety, especially when developed according to an evidence-based set of principles (Delhomme et al., 1999; Elder et al., 2004; Elliot, 1993; Elvik & Vaa, 2004; Phillips, Ulleberg, & Vaa, 2011).

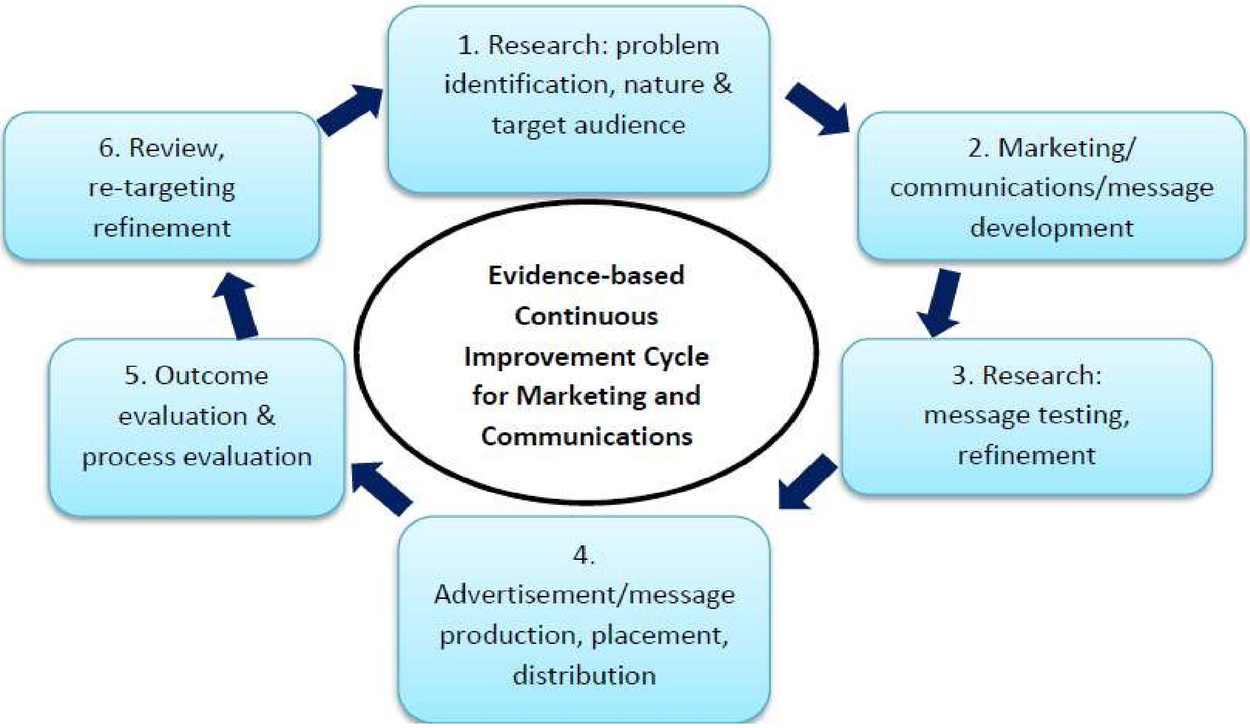
MAC undertakes media campaigns with paid advertising placements, electronic media, partnership programs and sponsorships which include communications to various audiences, editorials, media interviews, releases and responses. It is critical to understand which communications are working by how much, and for whom. Evaluation of communication programs allows more effective subsequent allocation of resources and evolving understanding of, and application of, the factors of success.

While evaluation is not easy or cheap, MAC has developed a practical Evaluation Strategy for road safety communications based on a review of international research and best practice. This paper describes this Strategy and offers a set of evaluation methods to be employed depending on the communication program and its context.

Evaluation Strategy Framework

The Strategy sets out the Evaluation Vision and Objectives. The Strategy is guided by MAC's value and commitment to evidence-based development-implementation-improvement cycle as described in Figure 1. The Strategy contains a Glossary (included at the end of the paper) for additional discipline and describes in detail the implementation for both process evaluation and outcome evaluation.

Figure 1. Evidence-based Road Safety Communications Improvement Cycle



Communication Program Type

Different types of communication programs are generally not distinguished because of common erroneous assumptions such as the simple assumed causal connections between attitudes and behaviours. In psychological reality, changes in apparently relevant attitudes may not result in expected changes in behaviour. Sometimes behaviour may change first and then generate a change in attitude (Job et al., 1997), and other times attitude change does lead to relevant behaviour change. Understanding these different types of communication programs is critical to effectively choose the most appropriate evaluation approach. To achieve this, the Strategy identifies three types of road safety communications, related to different causal sequences:

> **Type 1:** Influences behaviours directly, sometimes without and sometimes followed by attitude change.
> **Type 2:** Influences behaviours via attitudes.
> **Type 3:** Generates changes in attitudes or beliefs which allow more effective other actions (e.g. reduced speed limits, reduced BAC limits, increased enforcement or increased penalties) which will change behaviours.

Evaluation Implementation

The Strategy applies both process evaluation and outcome evaluation.

Process Evaluation

Process evaluation (including formative evaluation) involves the assessment of the integrity of the development and implementation of the program which influence the extent to which intended outcomes are achieved. Road safety communication programs can and should be developed in accordance with these evidence-based principles which have been demonstrated to enhance the likelihood of the success of a campaign in relevant research.

While many methods of process evaluation exist, the Strategy offers two methods of process evaluation which apply to all the three types of communication programs:

A. Analysis against a Best Practice Checklist which has been developed based on relevant evidence

The quality of road safety campaigns can be assessed against the following core good practice checklist of campaign development process, which has been based on the relevant evidence (CAST, 2010; Job, 1988; Phillips et al., 2011) and practical experience. The assessment is based on a yes/no determination. If the campaign development and design meet all the 15 criteria, the campaign is considered good international practice. Meeting five additional criteria listed under point 16 provides additional benefits and a campaign which meets all the 20 criteria is considered best international practice.

The road safety campaign:

1. Is explicitly based on a broader road safety strategy;
2. Is sufficiently funded;
3. Is based on a broad analysis of the situation to determine the applicability of the campaign;
4. Is developed in consultation with road safety partner organisations;
5. Is selected based on both the extent of the problem and the likely impact of road safety communications as a mode of intervention to address the problem. It is critical to assess this problem based on serious injury or death causation rather than simply on prevalence of the behaviour or all crashes;
6. Is based on well researched problem behaviours, beliefs and attitudes—uses a well-researched psychological theory as the conceptual base;
7. Is aimed at a specifically selected target audience, with soundly judged well research segmentation;
8. Addresses an explicit target behaviour with tailored message to the motivation and needs of these subgroups;
9. Is delivered in a mode/s which achieves maximum reach of the target audience and target behaviour based on research;
10. Has a specific objective (*Note*: General objectives such as ‘increase awareness’ are weak and not considered to have met good practice. Specific objectives such as ‘increase community acceptance of enforcement of speeding behaviour’ and ‘increase seat belt wearing on rural roads’ are required to meet good practice);
11. Is generated with professional creative;
12. Has processes for testing the creative such as through focus groups and audience testing;
13. Is developed with quality production values (i.e. the materials need to look credible, good quality, and have the right ‘look and feel’ for the audience);
14. Has ongoing tracking and monitoring of campaign outcomes through key performance indicators selected based on the campaign objectives;
15. Undergoes full outcome evaluation[1];
16. Meets additional criteria:

[1] See Tiered Outcome Evaluation options below.

16.1 Delivery at the state level;
16.2 Aligned with enforcement activities;
16.3 Content emphasizes the risk of detection;
16.4 Messages are based on less extreme and more common events rather than on fear or severe (but relatively rare) events;
16.5 Runs for a month or up to 3 months at maximum.

B. Estimation of effects based on Campaign Features as determined in the most recent meta-analyses of previous outcome evaluations

Many evaluation studies of road safety communication campaigns have been published in the scientific literature or described in various reports. An estimate of the likely benefits of road safety communication campaigns on reducing crashes and trauma was made based on the most recent and comprehensive available meta-analysis (Phillips et al., 2011). Beneficial effects can be broadly applied to estimate the value of a road safety communication campaign as follows:

1. Assume a 12% reduction in crashes from campaigns which meet all the 15 good core practice criteria above.
2. Apply a conservative allowance of 1% extra benefit if the campaign is run at the state (not national) level.
3. Apply a conservative allowance of 3% additional benefit when the campaign is aligned with enforcement activities and the message emphasises the risk of detection, or reduce by 3% when not.
4. Make no allowance for the emotional content (fear, fun, guilt, sympathy) because it is not clear that all these would work similarly well.
5. Assume the beneficial effects last for the duration of the campaign with a maximum duration of benefit of 3 months if the campaign lasts longer than this period.
6. Assume the net crash reduction applies equally to all crash severities in the absence of precise information provided by the meta-analysis.

The first method (A) is fundamental to the development of the communication program. The second method (B) is based on published evaluations, and so while it is also generally applicable to campaigns, the results are based on larger campaigns such that full published evaluations were undertaken. Thus, the effect estimation may only be applied to campaigns of sufficient size to achieve a strong reach. . Having an estimated outcome may help in communication to partners of the possible value (and/or justification) of the campaign.

Outcome Evaluation

Outcome evaluation involves quantification of the effectiveness of the communications in terms of road safety outcomes and the prescribed program aims. The ways in which outcome evaluation is conducted depend on the types of outcomes being measured and this may depend on the Type of communication programs. Therefore, the Strategy identifies outcome evaluation methods for each of the three Types of communication programs.

Outcome evaluations can impose significant costs, and thus the extent of evaluation depends on the budget as well as the size and the originality of the program being considered. More comprehensive evaluation is suited to larger and more original programs within appropriate budget and logistical considerations. Therefore, the Strategy offers a new approach identifying different Tiers of outcome evaluation as options for each Type of communication programs. The Strategy also describes the advantages, limitations and optimal use of each Outcome Evaluation Tier and provides brief notes on the ways to implement and the methodological rigour required for each of the outcome evaluation components.

Four Tiers of Outcome Evaluation for Communication Program Types 1 and 2

The Strategy describes four options for outcome evaluation of communication program Types 1 and 2 (Figure 2). It is recognised in the Strategy that it is also legitimate to choose *No Outcome Evaluation* in certain circumstances. Tier 1 involves all four evaluation components and is the most comprehensive evaluation option. Subsequent tiers have one less evaluation component from the previous higher Tier. The lowest level Tier 4 involves only one evaluation component.

Five Tiers of Outcome Evaluation for Communication Program Type 3

The Strategy provides five options for outcome evaluation of communication program Type 3 (Figure 3). As before, it is also legitimate to choose *No Outcome Evaluation* and Tier 1 involves all five evaluation components and subsequent tiers have one less evaluation component from the previous higher Tier.

Figure 2. Four Tiers of Outcome Evaluation for Communication Program Types 1 and 2

Evaluation component	Self-report assessment of program effects	Measures of people's use of website/social media in response to the campaign (*if relevant to the aims of the campaigns*)	Assessment of changes in crash, injury and deaths arising from relevant factors, and if reasonable cost calculations are available benefit cost ratio calculation for the program	Objective measures of the relevant target behaviour on the road
Tier 1				
Tier 2				
Tier 3				
Tier 4				

Figure 3. Five Tiers of Outcome Evaluation for Communication Program Type 3

Evaluation component	Self-report assessment of program effects, specifically targeting attitudes & beliefs regarding other possible road safety actions (e.g. changes in policy, law, or practice) to address the target problem	Measures of people's use of website/social media in response to the campaign (*if relevant to the aims of the campaigns*)	Success in obtaining relevant changes in policy, law, or practice (by MAC or partners)	Assessment of changes in crash, injury and deaths arising from relevant changes in policy, law or practice, and if reasonable cost calculations are available benefit cost ratio calculation for the program	Objective measures of the relevant target behaviour on the road

Tier 1					
Tier 2					
Tier 3					
Tier 4					
Tier 5					

How to make decisions on the optimal Tier

All the above evaluation options for communication program Types 1, 2 and 3 have advantages and limitations and the choice of which Tier is dependent on budget as well as what is optimum for each program. Tables 1 and 2 describe the advantages, limitations and optimal use of each Outcome Evaluation Tier for the three communication program Types. In addition, evaluations of Type 3 communications depend on timelines and connections between the communications and the subsequent relevant change of policy, regulation, or practice.

Table 1. Different Options for Outcome Evaluation of Type 1 and Type 2 Communication Programs: Advantages, Limitations and Optimal Use

Option	Advantages	Limitations	Optimal use
Tier 1	• The most comprehensive best practice evaluation • Direct future improvements & inform future practice • More confidence in the real impact on targeted behaviours • More confidence in attributing changes in crash, injury & deaths to changes in targeted behaviours	• Significant costs to develop & implement various data collection tools & evaluation design • Advance and long-term planning & implementation required	• Large-scale original programs • Observing behaviours is feasible • Sample size required to detect a change can be achieved
Tier 2	• Already existing data on crashes, casualties & crash savings can be applied • Identifies return on investment • Less costly than Tier 1 evaluation • Can direct future improvements & inform future practice but to a lesser extent than Tier 1	• Self-report survey development & implementation costs • Less certainty that changes in crash, injury & deaths were caused by actual behavioural change	• Large-scale original programs where objective behavioural data collection is not feasible (e.g. too large sample size requirement; unsafe data collection sites, budget constraints) • Small to medium-scale original programs
Tier 3	• Impact on digital media is known • Less costly than Tiers 1 & 2 • Completed in a reasonably short timeframe • Can direct future improvements & inform future practice but to a lesser extent than Tiers 1&2	• All Tier 2 limitations apply • Impact on crashes, injuries and deaths is not known • Return on investment is not known	• Small to medium-scale programs which are linked with website/social media
Tier 4	• The least costly form of evaluation • Completed in shortest timeframe of all evaluation	• All Tier 3 limitations apply • Self-report may not reflect true changes	• Small to medium-scale programs

	Tiers • Can direct future improvements & inform future practice but to a lesser extent than Tiers 1-3	in attitudes and behaviours • Impact on digital media is not known	
No evaluation	• Allow implementation of projects with limited budget & timeframe	• Program effectiveness is not known • Cannot direct future improvements & inform future practice	• Small scale communication programs (e.g. local community campaigns, or where sufficient sample size is not likely to be achieved) • Re-launch of a previously evaluated program (possibly with minor refinements)

Table 1. Different Options for Outcome Evaluation of Type 3 Communication Programs: Advantages, Limitations and Optimal Use

Option	Advantages	Limitations	Optimal use
Tier 1	• The most comprehensive best practice evaluation • Direct future improvements & inform future practice • More confidence in the real impact on targeted behaviours • More confidence in attributing changes in crash, injury & deaths to changes in targeted behaviours	• Significant costs to develop & implement various data collection tools & evaluation design • Advance and long-term planning & implementation required • Significant collaborations with partners	• Occasions where large-impact changes in policy, law, or practice occur • Observing behaviours is feasible • Sample size required to detect a change can be achieved
Tier 2	• Already existing data on crashes, casualties & crash savings can be applied • Identifies return on investment • Less costly than Tier 1 evaluation • Can direct future improvements & inform future practice but to a lesser extent than Tier 1	• Self-report survey development & implementation costs • Less certainty that changes in crash, injury & deaths were caused by actual behavioural change • Significant collaborations with partners	• Occasions where large-impact changes in policy, law, or practice occur but objective behavioural data collection is not feasible (e.g. too large sample size requirement; unsafe data collection sites, budget constraints) • Occasions where small to medium-scale changes in policy, law, or practice occur
Tier 3	• Impact on policy, law, or practice is not known • Less costly than Tiers 1 & 2 evaluations • Can direct future	• All Tier 2 limitations apply • Impact on crashes, injuries and deaths is not known	• Occasions where small to medium-scale changes in policy, law, or practice occur, but evaluation time or

	improvements & inform future practice but to a lesser extent than Tiers 1&2	• Return on investment is not known • Self-report may not reflect true changes in attitudes	budget is tight
Tier 4	• Impact on digital media is known • Less costly than Tiers 1-3 evaluations • Completed in a reasonably short timeframe • Can direct future improvements & inform future practice but to a lesser extent than Tiers 1-3	• All Tier 3 limitations apply • Impact on policy, law, or practice is not known	• Occasions where small to medium-scale changes in policy, law, or practice occur, but evaluation time and budget are tight • Program is linked with website/social media
Tier 5	• The least costly form of evaluation • Completed in shortest timeframe of all evaluation options • Can direct future improvements & inform future practice but to a lesser extent than Tiers 1-4	• All Tier 4 limitations apply • Impact on digital media is not known	• Occasions where small to medium-scale changes in policy, law, or practice occur, but evaluation time and budget are tight
No evaluation	• Allow implementation of projects with limited budget & timeframe	• Program effectiveness is not known • Cannot direct future improvements & inform future practice	• Occasions where small-scale changes in policy, law, or practice occur (e.g. at local council level)

Implementation of each evaluation component

A brief description of how to undertake the various evaluation components is provided below.

Self-report assessment of program effects: Classic self-report assessment involves surveying the target audience via door to door surveys, telephone surveys, mail-out surveys, or on-line surveys. Sample size depends on the statistical precision required, and the number of subsamples into which the full sample must be cut. In depth, but less objective, assessment of attitudes and values may also be achieved through focus groups, or content analysis of blogs and web activity. Campaigns which aim to change attitudes to certain government actions should have these set as explicit goals. Self-report survey questions can then be developed to assess relevant attitudes. For example, a campaign designed to reduce resistance to lower rural road speed limits could be assessed by asking respondents about the relationships between existing and lowered speed limits and road safety as well as other effects.

Measure of people’s use of website/social media in response to the program: Various electronic methods of tracking website activity are available. It is worthwhile to track time on site, and locations searched, as well as number of hits. However, use of social media and its evaluation for road safety benefits are relatively new approaches and more background research is required before significant investment is made. Most importantly, a clear relationship between web activity and behaviour or attitude/belief change must be established.

Success in obtaining relevant changes in policy, law, or practice (by MAC or partners): The ultimate success of programs which aim to change attitudes to certain government actions is the delivery of the relevant change, such as reduced speed limits, increased fines, increased enforcement or stronger enforcement methods (such as point-t-point) and assessment of the crash and on road behaviour changes generated by these changes (not by the advertising per se).

Assessment of changes in crash, injury and deaths arising from relevant factors: Most Australasian jurisdictions have an excellent crash database for such analyses. It is important to focus these analyses on before to after changes with precise start dates for communication campaigns (ideally with control jurisdictions for comparison), to manage the risk of capturing broad downward trends which may be due to various factors including improved safety of roads and safer vehicles.

Benefit cost ratio calculation for the program: Costs should be the full implementation costs of the program or campaign being evaluated. Normal account keeping processes for the organisation should provide these. Benefits may be calculated a number of ways, but will be based on estimated crash, injury and death savings over the period of influence of the campaign. Crash cost may be assigned through willingness to pay estimates (ideally), real economic estimates or a mixed method such as is employed by Bureau of Infrastructure, Transport and Regional Economics (BITRE).

Objective measures of the relevant target behaviour on the road: On-road observations of the actual behaviour are the only effective option for obtaining these data. These may be achieved by utilising already available objective data collected by partners or via new data collection (e.g. Observers standing at appropriate roadside locations to conduct observation surveys of seat-belt and child restraint, or rest stop use; Use of automated measurement, such as loops to measure vehicle speeds; Analysis of existing data, such as catch rates in RBT enforcement (controlled for various confounding factors of location, time of day and day of the week).

Practical Implications

Good road safety communications are created as a mix of evidence, rigour, sound use of creative development, outcome evaluation, process evaluation, inventiveness, and good judgement. Claims of constant success in road safety communications generally reflect insufficient rigour in evaluation processes and interpretations. Even with sound evidence-based development, an expectation that every road safety communication program will succeed is not realistic.

The Strategy approaches evaluation not only a success demonstration exercise but also a learning opportunity for future improvements. However, it is reasonable to expect that with good judgement and careful evidence based planning and execution, a net overall road safety benefit will be achieved from road safety communications, with successful programs creating sufficient benefit to cover the costs of less successful programs. This paper may assist in undertaking strategically selected evidence-based and practical approaches to determine the efficacy of road safety communication programs.

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Glossary

Advertising refers specifically to a form of communication designed to promote a particular product or behaviour. It is usually placed in media outlets or billboards, outdoor, or convenience locations, and normally involves payment for placement of the advertising, though media may place some (charity or community service) advertising for free.

Campaign refers to a series of coordinated communication activities including advertising and marketing.

Communications refers to the active exchange of information and meaning, by any technique. In a road safety agency such as MAC, communications typically applies broadly to all the information which is exchanged with the public directly or indirectly through media releases, stories, and interviews with the media, or through other outlets such as workplaces or road safety champions in various organisations. Communication is used as an overarching term referring to all forms and processes of advertising, campaigns, marketing and messaging.

Marketing refers to the process of communicating the value of a particular product or action, which may be seen as selling that product or action. In road safety, actions may include sticking to the speed limit, and products may include safer cars, helmets, or child restraints.

Message refers to the content of communications, advertising or marketing. In many instances the intended message may not be directly apparent, but relies on the viewer's interpretation of the scene or text.

Outcome Evaluation assesses the extent to which a program or campaign delivers the final intended beneficial outcomes. For example, in the case of road safety, the intended outcome may be reduced trauma though road traffic crashes. An outcome evaluation would be focussed on changes in death or injury in crashes. In order to allow improved precision in cause-effect inferences, this may be narrowed to specific types or locations of crashes, such as drink-drive crashes, or crashes in rural areas of the state.

Process Evaluation examines the development and implementation of a program or intervention. It assesses cause and effect relationships between what is done and outcomes, and includes assessment of the process details against intended targets and outputs. In the case of a road safety advertising campaign, a process evaluation may consider the extent to which the intended media uptake occurred, the access to the target audience achieved, and message take out as part of the processes by which the campaign could be expected to cause road safety benefits. For example, the message may have gone out on television but the intended audience may have received little exposure, or the audience may have seen the message but some sectors of the audience may have taken away an underlying message other than the intended message. Process evaluation is in significant part achieved through sound self-report surveys on the target audience.

Autonomous Vehicles: Human Factors Issues and Future Research

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Abstract

Automated vehicles are those in which at least some aspects of a safety-critical control function occur without direct driver input. It is predicted that automated vehicles, especially those capable of "driving themselves", will improve road safety and provide a range of other transport and societal benefits. A fundamental issue, from a human factors perspective, is how to design automation so that drivers understand fully the capabilities and limitations of the vehicle, and maintain situational awareness of what the vehicle is doing and when manual intervention is needed – especially for first generation vehicles that require drivers to resume manual control of automated functions when the vehicle is incapable of controlling itself. The purpose of this paper is to document some of the human factors challenges associated with the transition from manually driven to self-driving vehicles, and to outline what we can be doing in Australia, through research and other means, to address them.

Introduction

Background

The National Highway Traffic Safety Administration (NHTSA, 2013) states that automated vehicles are those in which some aspects of a safety-critical control function (e.g. steering, throttle control) occur without direct driver input. The shift to highly automated driving (HAD) is predicted to have a number of economic and ecological benefits. For example, Levitan and Bloomfield (1998) propose that automated cars will be more efficient than manual cars, increase predictability of trip times, and reduce environmental pollution due to a decrease in fossil fuel consumption and emissions. Fitch, Bowman, and Llaneras (2014) contend that highly automated driving will greatly improve safety by reducing crashes that result from human error, predominantly that associated with driver distraction. Work to identify the impacts, requirements and enabling mechanisms for the implementation of this technology in Australia, and elsewhere, is potentially the most significant program of cooperative investigation and forecasting reviewed in the transport domain this century.

The NHTSA (2013) in the United States has distinguished between five different levels of vehicle automation:

0. No automation – driver is in complete control of primary controls;
1. Function-specific automation – driver can give limited authority to a primary control (e.g., maintenance of speed via cruise control);
2. Combined-function automation – automation of at least 2 primary control functions working together (e.g., Adaptive Cruise Control and Lane Keeping Assist);
3. Limited self-driving automation – the driver may cede full control of all safety-critical vehicle functions under certain conditions but is expected to be available for occasional control;
4. Self-driving automation – in which the vehicle performs all functions and monitors roadway conditions for the entire trip.

Examples of market-ready vehicle automation in the Level 1 category include Adaptive Cruise Control (ACC) and Lane Keeping Assist, which assist with longitudinal or lateral vehicle control, respectively (‘functional-specific automation’; NHTSA, 2013). The combination of such automated systems is considered Level 2 vehicle automation (NHTSA, 2013), and Level 2 vehicles are expected to be available on the Australian market later in 2015. Google’s “Driveless Car” is an example of a Level 3 vehicle; it requires a driver to take control of the vehicle when it reaches the limits of its technical competence. A number of projects have demonstrated higher levels of automation in test vehicles in various research projects (HAVEit; Flemisch & Schieben, 2010). However, some research groups predict that full vehicle automation (i.e., Level 4) will not be implemented on British roads until 2030 (e.g., Walker, Stanton, & Young, 2001).

A key issue with HAD at this stage of its development is that it is not yet 100% reliable and safe (Martens & van den Beukel, 2013). Therefore, in situations in which HAD fails or is limited (e.g., sensory degradation in poor weather conditions; inability of on-board computer algorithms to make a safe decision), the driver will be expected to take control of the vehicle and resume manual driving. For this transition of control to occur safely, it is imperative that the driver fully understands the capabilities and limitations of HAD and maintains full awareness of what the vehicle is doing and when intervention might be needed (Cummings & Ryan, 2014).

In this paper we document some of the human factors challenges associated with the transition from manually driven to self-driving vehicles. The paper has two aims. The first is to highlight a number of human factors issues that influence the safety and efficiency of human intervention in automated driving and possible repercussions of automated vehicle use on driver skill and safety. Secondly, the review will discuss and underscore important research questions aimed at addressing these human factors issues.

Human Factors issues

Driver inattention and distraction

Although automation is usually intended to lighten driver workload, this is not necessarily beneficial for driving and does not always lead to increased road safety. If the workload on the driver is too little during periods of automation, the driver may experience passive fatigue, which is argued to stem from situations in which cognitive load is low and there a lack of direct control over the task at hand (Desmon and Hancock, 2001). Moreover, research has shown that passive fatigue can degrade overall driver performance. For example, increased vehicle automation is associated with reduced driver vigilance indicated by increased braking and steering reaction times in response to a sudden critical event (Neubauer, Matthews, Langheim, & Saxby, 2012; Saxby, Matthews, Warm, Hitchcock, & Neubauer, 2013). In the realm of HAD, this reduced vigilance and inattention may pose problems for drivers required to manually intervene during critical automation failures as these critical events may impose such a sudden increase in demand on the driver that the s/he may have difficulty dealing with it, and possibly crash (Young & Stanton, 1997).

Conversely, boredom may also proliferate from low workload in periods of automated driving. As a result, drivers may seek to engage in other activities (e.g., a task that is more entertaining) as opposed to monitoring and supervising the autonomous driving. Two recent studies conducted in driving simulators support this premise, showing that drivers are more likely engage in secondary activities and spend more time looking away from the forward roadway at higher levels of driving automation (Merat, Jamson, Lai, & Carsten, 2012; Carsten, Lai, Barnard, Jamson, & Merat, 2012). In essence, these findings suggest that drivers may be more vulnerable to distractions during periods of driving automation, posing a safety issue by compromising the ability of the driver to suddenly regain control of the vehicle when required. Several studies have demonstrated the adverse effects of secondary task demands on take-over time and quality in automated driving (e.g., Merat et al., 2012).

Situational awareness

Situational awareness (SA) is defined as “the perception of the elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future” (Endsley, 1995, p. 36). Colloquially, SA is an operator’s dynamic understanding of what is happening around them (Salmon, Stanton, Walker, & Jenkins, 2009). When drivers divert attention away from the automated driving task (i.e., distraction) or attention is diminished in the absence of a competing activity (i.e., inattention; Regan, Lee and Young, 2009), their level of SA will likely diminish as attentional resources are not being devoted to maintaining awareness of the vehicle state and road situation (de Winter, Happee, Martens, & Stanton, 2014). This reduction in SA in periods of automation can be dangerous as automation actions and alerts will likely be unexpected and come as a surprise to the driver (creating an ‘automation surprise’; Wiener, 1989; Hollnagel & Woods, 2005). For example, a driver that is occupied in some secondary task may fail to notice the autonomous vehicle navigating through foggy conditions (i.e., SA is low). In this instance, an alarm sounding to notify the driver that the automated systems are struggling in these conditions will come as a surprise to the driver. On the other hand, a driver that is paying attention to the road context (i.e. SA is high) will observe the onset of the foggy conditions and be ready for any automated failure alerts. Automation surprises can be detrimental to driver re-engagement time and quality as they may erratically increase driver workload, briefly rendering the driver unable to respond as a result (Vahidi & Eskandarian, 2003).

An insufficient level of driver SA can also lead to mode confusion. Mode confusion is a phenomenon that refers to a discrepancy between how the vehicle driver *believes* the vehicle to be operating and how the vehicle is *actually* operating (Cummings & Ryan, 2014). In lay terms, it is a sense of confusion concerning which aspects of vehicle performance is controlled by the driver and which is controlled by the automation at a particular instance (Martens & van den Beukel, 2013). If a driver is unaware of the state of the automated vehicle, he or she could make decisions based on the (incorrect) belief that the vehicle is in a certain state or in control of a certain aspect of driving when it currently is not (Bredereke & Lankenau, 2002). For example, a driver may reverse without looking with the (incorrect) assumption that operation of the vehicles’ reverse collision sensors would warn of potential hazards.

Overreliance and trust

As automated systems take over control of many driving tasks, drivers may learn to overestimate and over-rely on automation performance. *Overreliance* occurs when a driver does not question the performance of automation and insufficiently counterchecks the automation status (Saffarian, de Winter, & Happee, 2012). The phenomenon is synonymous with a sense of over-trusting automated systems, in which an operator’s trust in the automation exceeds its actual capabilities, resulting in the operator over-utilising it (Lee and See, 2004). However, too little trust may result in the technology being ignored and negating associated benefits with its use (Parasuraman & Riley, 1997). Therefore, trust in the system must be at an optimal (moderate) level.

The problem with overreliance and excessive trust in automated driving systems is that drivers may wrongly assume that the technology will warn them and intervene to prevent failure if and when necessary (Parasuraman & Riley, 1997). With this in mind, drivers may feel it is safe to engage in other activities, which will increase the propensity to become distracted (an issue for driver re-engagement) (Rudin-Brown & Parker, 2004), and adopt more hazardous driving behaviours (e.g., shorter headways; Hoedemaeker & Brookhuis, 1998) as the driver perceives the automation to be more capable than it actually is. These consequences of over-reliance in the automation are known as negative behavioural adaptation effects and can be detrimental to safe driving (Regan, 2004).

Skill degradation

Drivers that over-rely on highly automated driving systems may fail to use their manual driving skills over long periods of time (Parasuraman, Sheridan, & Wickens, 2000). The neglect of manual driving skills may, in turn, may degrade both the psychomotor dexterity and cognitive skills required to manually complete a task successfully and safely (e.g., Parasuraman et al., 2000). Ironically, this loss of skill may further encourage reliance on automation (Lee & Moray, 1994). The consequences of this skill degradation may be exacerbated in situations of automation failure as the driver may have difficulty resuming manual control of driving (Sarter, Woods, & Billings, 1997). In addition to the predicted long term effects (e.g., Rudin-Brown & Jamson, 2013), recent research has demonstrated that periods of automated driving may also impose more transient skill degradation. For example, a simulated driving study by Skottke, Debus, Wang, and Huestegge (2014) found that even brief periods of highly-automated driving were sufficient in impairing driving performance in a subsequent manual driving task, as evidenced by shorter headway times and increased variability of lateral position.

Motion sickness

A relatively unexplored, yet important, human factors issue in the realm of automated driving is that of an increased propensity for motion sickness of vehicle occupants. Motion sickness is a condition marked by symptoms of nausea, dizziness, and other physical discomfort (Golding, 1992) and can be associated with various modes of transportation (e.g., boats; Byrne & Parasuraman, 1996). The condition is most frequently caused by a conflict between visual and vestibular inputs (Benson, 1999), loss of control over one's movements (Rolnick & Lubow, 1991) and reduced ability to anticipate the direction of movement (Golding & Gresty, 2005). Interestingly, Sivak and Schoettle (2015) purport that up to 10% of American adults are expected to experience motion sickness often in autonomous vehicles. The authors also contend that remedies for motion sickness in the form of the design of the automated vehicle are limited as the crux of the issue is that automation controls the drivers' direction of motion, not the driver themselves, which may present issues of driver acceptance (see Regan, Horberry & Stevens, 2014).

Future research

The Transportation Research Board (TRB, 2013) has identified four priority areas for human factors research in the transition to highly autonomous vehicles. Here, we identify these issues, discuss previous research that has been aimed at addressing these issues, and forecast future research required to address them.

Re-engaging the driver

The process of how to efficiently and quickly re-engage the driver from automated driving in Level 2 and Level 3 autonomous vehicles is emerging as one of the key topics requiring research. Fundamental to this issue is the time frame required by drivers to successfully regain manual control of the vehicle. In reality, there is no optimal single or general take-over time; the time is likely to be influenced by a combination of variables such as traffic density, driver experience and driver engagement in secondary tasks at the time takeover is required (Zeeb, Buchner, & Schrauf, 2015). Despite this, preliminary research has shown that driver re-engagement may take between 5 and 7 seconds (Louw, Merat, & Jamson, 2015; Gold & Bengler, 2014). Merat, Jamson, Lai, Daly, and Carsten (2014) suggest that an additional 30-40 seconds may be required to stabilise driving behaviour once the transition takes place, especially in the event that the hand-over is unpredictable (which is especially relevant in the event of unexpected automation failure). However, the generalizability of these findings is limited due to the employment of simulated driving methodologies, which may not truly reflect critical situations in the real-world that one may assume would be more startling and stressful. Therefore, prospective studies need to (a) confirm the time budgets required for driver re-engagement using real-life driving methodologies and (b) corroborate how variables such as age and driving experience may moderate the quality and timing of this re-engagement. The mechanisms by which driver re-engagement is initiated will be discussed below.

The user interface and the communication of automation limitations

Optimal design of the human-machine interface (HMI) in autonomous vehicles is critical for safe driving, as the HMI is the point of communication between system and driver. During periods of automation, it is critical that the HMI keeps the driver involved in the driving task and aware of the vehicle status and road traffic situation (i.e., keeps the driver 'in-the-loop'). Regan (2004) contends that the HMI must clearly communicate the automation status and limitations in an ergonomically-appropriate way that is both clearly visible and easy to monitor (at all times) to prevent automation surprises. It is paramount that the HMI maintains SA in the driver and that the driver does not fall 'out-of-the-loop', as this will impair re-engagement in conditions of automation failure (Louw et al., 2015).

Where automation failure is imminent, the HMI will need to signal a manual take-over request that carefully balances urgency and driver workload. Recent research has examined how the timing and modality of signals or alerts may influence driver behaviour in such safety critical situations. For example, HMI signals must be appropriately timed to ensure that they are (a) not too late as to give the driver sufficient time to successfully re-engage, and (b) not too early as that may be interpreted as a false alarm and be perceived as a nuisance for the driver (Lee & Lee, 2007). In addition, it is still unclear how multiple unfolding conflicts should be communicated to drivers as different alerts (signalling these multiple conflicts) that occur temporally close (or concurrently) may startle and confuse the driver, potentially augmenting driver reaction time in response to the situation (Fitch et al., 2014). In terms of the optimal modality of communicating a hand-over request, signals that are visual-auditory have been found to result in more efficient and safer re-engagement compared to those purely visual, which may not even be detected if the driver is distracted (Naujoks, Mai, & Naukum, 2014). Future research needs to continue to elaborate on the interplay between HMI design and take-over situations to ensure the automation state and limitations are communicated to the driver in the most optimal and holistic way possible to ensure safe driving.

Automation misuse and the need to monitor the driver

Drivers may misuse autonomous vehicles whenever attempts are made to operate it outside of design parameters. As discussed previously, drivers may have too much trust in the automation and feel it is safe to engage in other tasks (which will impair re-engagement if required) or place the vehicle in riskier driving manoeuvres (which the car is not capable of performing safely). Both of these issues of misuse may curtail safe driving (Regan, 2004).

Future research needs to be devoted to identifying how education, training and licensing may be used as a countermeasure for automation misuse in the future. For example, training programs should ensure the driver understands how to operate an autonomous vehicle safely, and understands its fundamental capabilities and limitations (Stanton & Young, 2005; Rudin-Brown & Parker, 2004), and becomes aware of the dangers of becoming too reliant on the technology (Regan, 2004). In addition, NHTSA (2013) argues that education needs to be devoted to ensuring drivers know how to resume control of the automation in the event that it cannot continue to operate automatically.

Where drivers do misuse automation and become distracted or inattentive, driver state assessment technology (DSA) might be used as a mitigation strategy. DSA monitors the driver's alertness and attention level in real-time, reorienting the driver's attention to the driving task he or she is judged as being "too distracted" from or inattentive to (e.g., when drowsy) according to some predetermined criteria (Rauch, Kaussner, Krüger, Boverie, & Flemisch, 2009). This can be deduced from (a) direct measures including degree of head rotation and direction of eye-gaze (i.e., away from forward roadway; Boverie and Giralt, 2008; Wierwielle, 1999; Hargutt, 2000) and (b) vehicular metrics such as lane keeping performance (i.e., poor lane keeping performance as a sign of driver inattention; Stephan, Hosking, Regan, Verdoorn, Young, & Haworth, 2006).

Preliminary research into the benefits of DSA technology and concurrent feedback to help drivers modulate distracting activities seem promising (Donmez, Boyle, & Lee, 2008). For example, recent trials of head rotation-monitoring systems have been shown to reduce distraction event frequency by almost 80% through distraction alerts and real-time feedback (Croke & Cerneaz, 2009; Heinzman & Zelinsky, 2010). In addition, a recent simulated driving study (Zeeb et al., 2015) showed that eye-gaze behaviour during automated driving can serve as a reliable predictor of the readiness to take over control of the vehicle. Despite initial success, future research will need to further scrutinise DSA technology. Studies need to focus on how the technology can address variability between drivers and different expressions of fatigue and drowsy states (Rauch et al., 2009), as well as privacy issues that may be elicited, which may affect the extent to which automation technology is accepted and utilised.

The personalisation of automation

Another prominent question in the domain of automated vehicles regards the level of standardisation among automated operations and interfaces (TRB, 2013). It is doubtful that different car companies will develop automated systems in similar ways, therefore giving the systems a high level of diversity. In a recent review, Saffarian et al. (2012) support this diversity suggesting that display and automation settings need to be configurable based on operator preference to ensure drivers can interact with it efficiently. However, a number of researchers note that this diversity and personalisation of automated systems will create issues for interoperability and that these systems should behave consistently so as not to violate driver and road user expectations (e.g., if a driver attempts to operate a different automated vehicle to their own) (Burns, 2014). This is an important area of research as the personalised dimensions of automated driving adjustments may be key for user acceptance.

Acceptance

Acceptance of autonomous vehicles is of paramount importance as it will determine whether the systems will actually be used. If automated driving is perceived as unacceptable (unreliable or not useful), drivers may refuse to use it and negate all associated benefits (Regan, Horberry, & Stevens, 2014). For example, ACC has been typically well received based on its perceived convenience and improved safety, however many are still sceptical and fail to utilise the technology in fear of system limitations and sensor degradation in particular (e.g., foggy conditions) (Larsson, 2012). In addition, platooning, which is the grouping of vehicles maintaining a constant short headway achieved by sensor technology, is a driving manoeuvre anticipated for future autonomous vehicles that may have issues with acceptance. A recent report (Larburu, Sanchez, & Rodriguez, 2010) suggests that men may be more tolerant of the short-headways envisaged for this style of driving compared to women, and that participants reported feeling uncomfortable at inter-vehicle distances of 16m and smaller. However, this is a distance greater than that considered to be energy efficient and safe in platooning (Larburu, Sanchez, & Rodriguez, 2010).

In regards to fully autonomous vehicles (Level 4 automation), a recent survey of public opinion provided insight into the types of issues that are most worried about (Schoettle & Sivak, 2014). For example, safety consequences of the system, the potential for the vehicles to become confused by unexpected events, legal liability for drivers and owners, or system security (e.g., hackers) are issues that are receiving considerable attention. On the other hand, issues such as how a driver would learn to use an autonomous vehicle or system performance in poor weather were less relevant issues, a finding which is surprising given the driver concerns noted by Larsson (2012). From this, it is apparent that there are still a range of issues and concerns that may act as a barrier to the acceptance of autonomous driving technology. These issues must be addressed to ensure that drivers utilise the technology and their associated safety benefits.

Conclusions

This brief review of the literature has highlighted a range of human factors challenges that will need to be addressed during the transition from fully manual to fully automated driving. Autonomous vehicle technology is not yet completely safe and reliable, therefore necessitating driver input when autonomous systems fail or are limited in their performance capabilities. The shifting role of the human driver from one in which they are in total control to one in which they are responsible primarily for monitoring and supervising the driving task may lead to problems of inattention, reduced situational awareness and manual skill degradation. In turn, these human factors may compromise the safety of manual control in cases where autonomous systems fail.

As automated technologies are being implemented in an increasing number of market-ready vehicles, there is an immediate and urgent need for future research to address these human factors issues. Studies need to be aimed at enhancing our understanding of how to safely and efficiently re-engage the driver and in designing the automated vehicle from a human-centred perspective. Investigations also need to identify potential misuses of automation and develop countermeasures to reduce behaviours such as overreliance. Finally, research should be devoted to further elaborating on the pros and cons of enabling the personalisation of automation systems and understanding, more generally, barriers to the acceptance of highly automated vehicles. Collectively, these avenues of research will play a vital role in ensuring that automated vehicles realise their potential benefits in increasing road safety.

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Older drivers' perceptions and acceptance of vehicle safety technology

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Abstract

Older drivers have a higher risk of injury in a crash than the general driving population due to increased frailty. Vehicle safety is therefore particularly important for older drivers. This research explored how older drivers perceive new and emerging vehicle safety technologies, and investigated the current understanding they have of these technologies and their likely uptake of these technologies. A qualitative phase of the research consisted of eight 45-minute in-depth interviews, while a quantitative phase included an online survey of 1,070 older drivers. Participants were required to be aged 60+, live in Victoria, and have either purchased a vehicle in the last 12 months or intended to do so in the next 12 months. The results found that older drivers perceived vehicle safety technologies as a primary factor impacting overall vehicle safety. However, participants had very little knowledge and awareness of some of the newer safety technologies that are emerging on the market (e.g. blind spot warning, autonomous emergency breaking, lane departure warning). Older drivers were less concerned with the intricate working details of these technologies, and instead wanted to be reassured that they would help keep themselves and their passengers safe. Participants were open to adopting newer vehicle safety technology, but believed the role should be to act as a 'just in case' measure, rather than replace driver skill. It was therefore considered that communication messages should tap into the emotional aspects of safety, by providing reassurance and peace of mind that the technology will provide protection to the driver and passengers, rather than focus on the mechanics of how the technologies operate.

Introduction

It is well established that Victoria has an ageing population, with the proportion of Victoria's population aged 65 and above expected to grow from 14 per cent to around 21 per cent by 2051 (Department of Transport, Planning and Local Infrastructure, 2014). Although older drivers do not currently represent a large road safety problem when compared to younger drivers, an ageing population naturally suggests there will be an increase of older drivers on the road and that the safety of these drivers will become a critical issue.

A major concern for older drivers is their capacity to survive a crash. Frailty increases with age meaning older drivers have a higher risk of sustaining a serious injury in a crash (Evans, 2001). For example, people aged 80 years are five times more likely to sustain a seriously injury resulting in death in a crash compared to people aged 50 years (Li, Braver & Chen, 2003). This renders vehicle safety particularly important for older drivers.

Previous research commissioned by RACV explored the issues relating to older people and their knowledge and awareness of vehicle safety features, finding that features related to comfort, ease of driving, and vehicle handling were the most important to older drivers (Charlton et al, 2002). Specific safety features that improve occupant protection in a crash were poorly understood and misconceptions about features such as airbags were common.

There have been significant advancements in vehicle safety technologies emerging on the market since the earlier RACV research was conducted (e.g. Autonomous Emergency Braking, Adaptive Cruise Control). Very little is known about how older drivers perceive these new technologies.

There is a need to better understand the uptake of vehicle safety technologies among older drivers and their knowledge of the safety benefits these technologies can provide.

The current research will investigate older drivers' perceptions and acceptance of new vehicle safety technology, to determine what understanding they have of the technologies available. The research also aims to gain an understanding of the decision making process undertaken by older drivers when purchasing a newer vehicle, with a specific focus on knowledge of, and consideration given, to vehicle safety technology.

Methodology

A qualitative and quantitative phase of the project was designed. Participants for both phases were required to be 60+; live in Victoria; have a current Victorian drivers licence; have not recently worked in the road safety or related industry; had either purchased a vehicle in the past 12 months or intend to purchase a purchase a vehicle in the next 12 months; be the main or joint decision maker; and have purchased a vehicle that was no more than three years old at the time of purchase (i.e. 2011 or later model).

The qualitative research phase included eight depth interviews that were conducted with older Victorian drivers: four with older drivers who had purchased a vehicle in the past 12 months and four with older drivers who intended to purchase a vehicle in the next 12 months. The interviews were conducted by telephone and were approximately 45 minutes in length. Interviews were spread to ensure reach across gender, age and location even though true representation was not feasible across eight interviews.

The quantitative research phase included an online survey of 1,070 older drivers. Table 1 outlines the demographics of the participants. Participants were sourced from the RACV membership email database and RACV enews subscriptions. The results in the report are representative of the RACV membership database aged 60 and above. Data was weighted based on all older drivers who accessed the survey and completed the screening criteria, taking into account age, location (metro vs regional Victoria), and gender.

Table 1. Demographics of participants

Gender		**Location**	
Male	**Female**	**Metro**	**Rural**
610	460	695	375

Age Groups				
60 – 64	**65 – 69**	**70 – 74**	**75 – 79**	**80+**
289	278	182	150	171

Results

Older drivers' car use

Older drivers reported a high frequency of car use. Almost half of all older drivers reported using their cars every day, and 80% reported using their cars at least 5 times a week. While a variety of reasons for using a car was reported, it was the convenience of being able to do every day errands (e.g. trips to the supermarket or attending appointments), travelling to nearby areas, and attending social activities that cars were mostly used for.

Despite qualitative insight that travelling longer distances by car may decrease with age, the quantitative phase did not find that age played a factor in how older people used their cars, other than for travelling to work, which significantly decreased as age increased. This was not an unexpected finding given people retire as they age.

What prompts older people to consider purchasing a newer vehicle?

As shown in Table 2, a high proportion of older drivers reported that needing a more practical and/or reliable car was a factor that triggered the need to purchase a newer vehicle.

Table 2. Factors that trigger the need to purchase a vehicle

	Total mentions	Main mentions
Practical		
Car getting too old / reaching end of its run	43%	19%
Had current car for too long	35%	9%
Not wanting to lose too much value on re-sale / trade in	18%	7%
Wanting a more practical car	18%	3%
Reliability		
Avoiding high cost of repairs / maintenance / things going wrong	33%	9%
Wanting a car that is more economical to run	29%	6%
Wanting a more reliable car	14%	2%
Change of Lifestyle		
Approaching retirement / just entered retirement	18%	4%
Addressing health issues (e.g. ease of getting in/ out of car)	16%	6%
Changes in the way I use a car (frequency, or distance travelled)	6%	1%
Safety		
Wanting a safer car	26%	6%
Indulgence		
Fun and excitement about driving something new or different	13%	2%
To indulge or treat myself	12%	3%
Wanting a more expensive or luxurious car	6%	1%
Fulfilling wish of having my dream car	4%	1%
The status or prestige of having a new car	3%	0%
To be envied or admired by others	1%	0%
Other		
Wanting a smaller car	20%	5%
Reducing number of cars owned within household	4%	1%
Wanting a bigger car	6%	2%
Other (e.g. towing requirements, car written off / damaged etc		12%

Purchasing a newer vehicle appeared to be a way for older drivers to mitigate future vehicle expenses, by avoiding the high cost of repairs and maintenance, and also by avoiding any potential issues the car might have in the future. In particular, the qualitative phase noted a perception that if anything goes wrong with a vehicle that is over 10 years old it will require significant investment.

Purchasing a newer car was also an opportunity to obtain a vehicle that runs more efficiently and economically than the current vehicle.

The qualitative discussions found that in instances where a car was not approaching the end of its running life, there was a need to seek a vehicle that better accommodated driver requirements. For example, a new vehicle may be purchased as it provided the opportunity to consolidate existing vehicles which then allowed couples to share. Vehicle consolidation was generally associated to lesser car use or infrequently travelling alone. A physical or mobility issue that may be impacting the ease of getting in and out of a vehicle for either drivers or passengers was also a reason for vehicle purchase. Other reasons reported included upsizing to accommodate grandchildren or downsizing to make it easier to get around (e.g. parking).

The research explored whether planning or preparing for retirement influenced purchasing decisions, which was found to be a factor for only a small proportion of older drivers. Additionally, qualitative insight suggested many of these purchases may also be considered as a treat or present to themselves, rather than filling a specific transport need.

Some participants also reported that although they had planned or considered purchasing at retirement or shortly thereafter, waiting a bit longer enabled them to consider how their car use might change during retirement, in terms of frequency of use or the number of vehicles required for the household. Those that purchased at retirement also did not necessarily indicate that it would be their last car, and were generally open to purchasing another car if the need arose.

A small proportion of older drivers (6%) reported that wanting a safer car was a reason that triggered their need to purchase a newer car. Of those, people aged 70-74 (9%) were significantly more likely to report safety as their main reason for purchasing a car when compared to the rest of the participants (6%). The overall results suggest that wanting or needing a safer car was not necessarily a prominent reason why older people considered purchasing a newer vehicle. Rather, ‘safety’ became a more important factor when the thought process shifted to considering specific vehicles that could be purchased.

Factors that influence purchasing decisions

Decision criteria

The qualitative interviews identified that a range of decision criteria were used to assist in evaluating potential vehicles for purchase. Rather than giving weight to all criteria to provide an overall evaluation, the criteria was used as a process of elimination of potential vehicles that may be suitable to assist in narrowing down to a final choice. Failure of a vehicle to meet particular criteria resulted in it being removed from consideration. For instance, if the price was out of budget, or if there were any negative reports about the car, such as safety issues or other problems with reliability, then the car would no longer be considered.

Table 3 shows how older drivers rated decision criteria in the quantitative phase as part of their purchase and also which criteria they reported was their main and most important factor when considering vehicle purchase. As can be seen, older drivers considered the ‘safety of a vehicle’ and the ‘driving experience’ as the main criteria when considering specific vehicles that could be purchased.

Interestingly, the research found that the 60–64 year olds (15%) were significantly more likely to focus on cars that are modern (and consequently have newer technology) than the 75+ age group (6%).

Table 3. Criteria older drivers considered when purchasing a vehicle.

Criteria for car selection	% consideration as part of purchase	% consideration as main factor
Drive (comfort / easy to drive / quiet / reliable)	83%	26%
Safety (technology / design / ANCAP)	71%	27%
Economical (fuel economy / running costs / warranty / included servicing)	66%	11%
Modern (overall design & style / features, e.g. heated seats, aircon, parking sensors, GPS)	64%	11%
Price	54%	14%
Size of car	36%	9%
Indulgence (luxury or prestige / enjoyment / belonging to or joining a club)	8%	2%
Experience of visiting a car dealership	5%	0%

New vehicles vs used vehicles

The majority of older drivers (79%) indicated an overwhelming preference for purchasing new cars over used cars. This was because purchasing a new car provided a number of benefits such as being more reliable (81%), and newer cars have the latest features, which makes driving more comfortable (64%). Those that reported they would prefer to purchase used cars (13%) did so because they are more economical/affordable/not decrease in value as much (82%), and because they considered a near new car as almost as good as new (77%).

A high proportion of older drivers (43%) also reported that they prefer new cars because they are safer than used cars. Of the older drivers that reported they preferred used cars, only 1% believed that purchasing a used car would be safer than a new car. However, it should be noted that these results may have been influenced by the selection criteria of having purchased or intending to purchase a vehicle that was no more than three years old.

Resources used to inform purchasing decision

A combination of printed and online information sources were consulted as a key reference to obtain information on the vehicle. The main sources included internet websites (e.g. car, motoring, RoyalAuto website; 75%), printed publications (e.g. RoyalAuto, newspapers, classifieds; 69%), experience during test drives (47%) and car dealerships (46%). However, it is important to note that these results may have been biased towards RACV resources and internet based resources given the participants of the quantitative phase were RACV members sourced through email invitation and RACV enews subscriptions.

Qualitative insight revealed that while obtaining information directly from manufacturers was useful in providing vehicle specifications, information from manufacturers was perceived as being designed to market the vehicle and show it in its best light. Independent reviews and word of mouth were considered as more trustworthy and reliable sources of information.

Generally older drivers wanted an informed and impartial viewpoint to gain honest feedback on a car's strengths and weaknesses before purchase. This also included awards and endorsements that a car performed well, which would result in a vehicle being worthy of consideration. However, it was not always necessary for a review to be glowing – older drivers simply wanted an honest review to enable them to consider the vehicle in light of their own requirements and criteria. It should also be noted that while positive reviews from trusted sources would provide assurance, any negative reviews or feedback would immediately exclude the vehicle from consideration.

Visiting a dealer was also an important way for older drivers to gather information about a vehicle, although, this was usually the final part of the decision making process. For example, going for a test drive had the potential to 'make or break' the decision, while at the same time more information could be gained at this stage which may result in the purchaser reconsidering or researching new information.

Perceptions of vehicle safety

Qualitative findings found that many older drivers viewed the overall car design a good indicator of vehicle safety. In particular, cars that are bigger, have a solid and sturdy design, and appear 'stronger than a tin can' provided a sense that a car was safer than others.

This was somewhat supported by the quantitative findings, as can be seen in Table 4, which shows these factors were rated in the middle of the range as factors that impact on safety. Table 4 also shows that older drivers reported vehicle 'safety features and technologies' as the main factor that they believed impacted overall vehicle safety. However, it is important to note, that when asked to recall safety features the participants defaulted to 'standard inclusions' such as airbags, ABS braking, and five star safety ratings. Therefore it is unlikely that older drivers were considering some of the newer vehicle safety technologies (e.g. AEB, adaptive cruise control etc.) when responding to this question.

Table 4. Factors that older drivers perceive impact overall car safety: 10 – High impact; 0 – No impact.

Factor that impacts car safety	Perceived impact
Features / technologies within the car specs (e.g. ABS braking, airbags etc)	9.1
Skill of driver behind the wheel	8.3
Safety info from independent orgs (e.g. safety ratings, crash test reports)	8.0
Reputation of manufacturer	8.0
A solid or sturdy design	7.9

Safety info from the manufacturer	7.2
Buying the latest model	6.4
Car size (bigger cars safer than small cars)	6.0
The price paid for the car	5.9
Awards won by a car	5.7
Buying a top of the range car model	5.1

The qualitative interviews identified a fine line between the importance of having a 'safe' car and the appropriate skill as a driver to deliver safety while on the road. Attitudes towards safety features appeared impacted by a lack of understanding and cynicism toward new technology. The quantitative findings somewhat supported the qualitative findings, with many highly rating the 'skill of the driver' as an important part of a vehicles overall safety. The general perception was that it was the drivers' responsibility to remain alert and aware of impending danger and have the appropriate skills to handle situations that arose, without assistance from technology. The technology should only be there as a 'backup'.

Table 4 also shows that safety information from independent organisations and good reputation of a manufacturer had a high impact on perceptions of overall vehicle safety. Once older drivers were assured from a reputable and trusted source that a car was safe, it effectively negated the need to investigate specific safety technologies in further detail. Safety features were considered as a 'hygiene factor' list that must be ticked before a buyer moves on to the economic and status considerations. The extent of any further consideration into what technologies a car has might involve double checking standard inclusions off a list of criteria, or potentially considering the number of airbags available.

Instead of being concerned about the specific safety technologies that a car might have, older drivers appeared to be more concerned with the highly functional aspects of safety, in terms of ensuring their personal safety and the safety of loved ones when passengers. In addition, health related issues such as being fit to drive, getting around when no longer driving, and vision impairment were important to older drivers. There was also a general trend for older drivers to report higher concerns with these factors as they aged, which suggests ageing is associated with greater awareness or experience of these issues. These findings suggest that although there is an important need for cars to be safe, there is a stronger need for older drivers to feel safe when travelling in a car to minimise the impact of these concerns.

Older drivers' awareness, knowledge and understanding of vehicle safety technologies

Older drivers did not have a high level of knowledge or awareness about some of the newer vehicle safety technologies emerging in the market. Trying to recall vehicle safety technologies was difficult, and was generally limited to familiar features and standard inclusions that are readily available. Those able to recall newer technologies mentioned things such as parking sensors and cameras, adaptive cruise control, fatigue warning, anti-crash or anti-collision technologies, and stability control.

When prompted with a list of specific newer technologies awareness somewhat improved. Specifically, the key technologies older drivers reported being aware of included blind spot warning (68%), driverless cars (66%), adaptive cruise control (65%), autonomous emergency breaking (65%), and lane departure warning (63%). Interestingly, driver age did not impact on awareness of specific safety technologies, except for AEB, where the 70+ age group was found to be significantly more aware than the rest of the participants.

Participants reported being aware of these technologies through direct experience when travelling in a friend's car, which not only provided a first-hand demonstration of features available but was also a way of receiving feedback about the technology from an independent and trusted source. Although experiencing technologies in this way increased the risk of technologies being perceived as a novelty or a gadget, there was also a way for the technology to be perceived as a practical or smart function that related to one's own driving experiences. Positively, it also created interest and desire for intended purchases.

Media coverage was also effective in bringing attention to some technologies (e.g. anti-crash technology/driverless cars), although somewhat ineffective in creating memorability around the detail. For example, there was generally very little understanding about what many of these technologies were designed to do. Prompting participants with the names of some technologies proved intuitive in enabling them to provide an assumed interpretation of what the feature or function was designed to do. This was particularly relevant for those that were variations or enhancements of current features (e.g. adaptive cruise control).

In other instances, names were ambiguous leaving participants unsure as to what may be offered (e.g. vehicle to vehicle/vehicle to infrastructure). This suggests technologies with technical terms may be perceived as too complicated and ambiguous, leading to avoidance rather than further investigation.

Resources used by older drivers to gather information about vehicle safety technology

Older drivers reported a preference to gain information about vehicle safety technology from independent sources. In particular, RACV's Royal Auto magazine and online content combined to be the preferred information source for 83% of the participants (magazine only – 73%; online only 58%). However, it is important to note that these results may have been skewed given the participants of the quantitative phase were RACV members. Regardless, these results suggest RACV is well placed to further communicate and to educate its older members about vehicle safety.

Other preferred information sources were the internet (67%), while some preferred to get their information directly from vehicle manufactures websites (61%) and crash test results (50%). There was also evidence of aged based differences in these sources, in particular a prevalence of online sources for the 60-64 year olds, and family/friends for 75+ year olds.

Overcoming the barriers to older drivers adopting vehicle safety technology

Generally, older drivers were open to vehicle safety technology helping them to stay safe on the road, and reported that they would feel safer behind the wheel if they had safety features and technology in their car. However, engagement with older drivers is more likely to be effective if communication messages focus on the direct safety benefit of the technology, and also if there has been some form of real world experience with the technology (e.g. during a test drive or passenger in a friend's car) rather than trying to explain how the safety features work from a technical point of view.

As older drivers are unlikely to investigate individual safety technologies as a part of their decision making process and are more likely to focus on independent reviews of a cars overall safety, a potential barrier to uptake of newer safety technology is likely to be if the technology does not form part of the vehicles standard inclusions. This barrier may be enhanced by the common perception that technologies that are not standard inclusions would result in an additional cost, which runs the risk of exceeding the budget allocated to vehicle purchase. In this scenario, it is most likely that the purchaser would either consider another vehicle or settle for a more basic model, meaning the technology would not be adopted. Beyond the initial costs of obtaining a vehicle with the technology, older drivers were also concerned and mindful of the potential expense of repairs or maintenance of safety features.

Awareness of available technologies and their associated benefits is also considered critical. If there is no awareness, then there is no knowledge of the safety benefits the technology can provide. There are many online and printed independent resources that are used by older drivers to obtain more information about vehicles and technology, which suggests these resources are well placed to increase awareness, knowledge and understanding about the benefits of safety technologies available. Purchasers need to understand the benefit technologies provide in order to be necessary and justified for inclusion – essentially a justification for “Why do I need this?” or “Why should I have this in my car?”

The research also found that direct experience with safety technology was important in how people perceive and understand safety technology. Visiting a car dealer was generally identified as one of the final parts of the decision making process and is an opportunity for more information to be provided. However, the risk with this information being provided by the manufacturer or salesman may result in the information being perceived as a sales pitch or gadget rather than something that can provide an important safety benefit.

Therefore, promotions or communications about vehicle safety technology may also benefit by encouraging older drivers to test drive a vehicle and experience the benefits of the technology themselves. Alternatively, promotional campaigns around specific technologies, such as AEB, may find it beneficial for attendees to experience the effect of the technology through a driving simulator or other ‘real world’ demonstrations.

Although older drivers found vehicle safety technologies interesting, there was a fine line about whether the technology is designed to assist drivers or compensate for lack of skill, which impacted perceived reliance and need for features against driving experience. This appears to reflect a common perception that too much technology may result in reliance on technology to do the job that the driver has previously been required to perform. As a result people may become less aware of impending danger around them and also subsequently become more distracted. This possibility appears to make people more reluctant to accept that this type of technology may become more common. While this may be a common concern, the importance of driving experience should be consistently reinforced with the focus being on how the safety technology is designed to assist drivers for those ‘just in case’ situations.

Conclusion

The findings of this research were consistent with earlier RACV research that found vehicle features relating to comfort, ease of driving, and handling were important to older drivers.

Older drivers also reported limited knowledge and understanding of specific vehicle safety technologies. While this may suggest there is a good opportunity to address gaps in the current knowledge and understanding older drivers have of vehicle safety technologies, there is a clear lack of interest in learning about how vehicle safety technologies work. Rather, older drivers simply want to be reassured that the vehicle they are considering purchasing will keep themselves and their passengers safe.

Older drivers consider the standard safety features of a vehicle (e.g. airbags, ESC) as an excellent guide to the vehicles overall level of safety. Therefore, if some of the most promising newer safety technologies (e.g. AEB) were to become ‘standard safety inclusions’ for all new cars, this would improve perceptions of vehicle safety as well as facilitate uptake of these features. On the other hand, if technologies such as AEB are only available as an optional extra with an additional cost, then this technology is unlikely to influence perceptions of safety, and uptake will be less likely.

The current research found that third party resources, such as RACV’s Royal Auto and general motoring internet sites and magazines, are the most trusted sources of information. Reassuring and educating older drivers about vehicle safety is likely to be most effective if it is facilitated through these resources. Effective communication within these resources should tap into the emotional aspects of safety by providing reassurance and peace of mind that the vehicle will keep themselves and their passengers safe in those ‘just in case’ situations.

Additionally, information that focuses on people being at a higher risk because they are older is likely to be ineffective. Rather, older drivers are mindful that certain health and medical conditions increase with age, hence communications are more likely to be effective if they focus on how health and medical conditions can increase crash risk, and how safety technologies can help to reduce such risk on the road.

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Dynamic assessment of aftermarket child restraint accessories – are there any safety implications?

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Abstract

There are many aftermarket child restraint accessories available on the Australian market, such as the gated buckle (used to convert a lap/sash belt to a lap only belt) and the chest strap (connects to the harness straps to make it harder for a child to remove their arms). These products are often perceived as serving a safety need, such as the chest strap preventing a child from removing their arms from a harness and being partially unrestrained. However, it is unknown if these products interfere with the safety performance of the restraint or present a hazard in themselves. This research explored whether adding an aftermarket accessory to a child restraint either affects the performance of the restraint or presents a safety hazard in the event of a crash. A test protocol was developed and dynamic testing was subsequently performed to determine whether any safety implications existed for two specific aftermarket child restraint accessories - the gated buckle and chest strap. The gated buckle was tested on both rearward and forward facing child restraints, while the chest strap was tested on a forward facing child restraint only. The results were compared to baseline dynamic test results that were performed without the accessory. This paper will report on the dynamic assessment process and will discuss whether any safety implications or hazards result from the use of these devices. Recommendations around the use of these devices will also be discussed.

Background

There are various aftermarket child restraint accessories that are commonly used by parents. These devices are often used with the intent of improving child safety when travelling in a vehicle. In 2012, RACV commissioned research to undertake a desktop review of a variety of these accessories (Paine, Paine, Brown & Bilston, 2012). This work identified that many accessories had potential safety risks. Two of these devices, the gated buckle and the chest clip, warranted further investigation.

The gated buckle is a device that is designed to convert a lap/sash seatbelt into a lap only belt. It is generally used to provide a tight, secure installation of the child restraint and to ensure the restraint remains in the installation position throughout ongoing use. Previous RACV research identified that depending on how it is used, it may allow excess slack in the lap section of the belt and that it could also come into contact with the child in the event of a crash (Paine et al, 2012). There are also concerns that in a crash it may become unthreaded from the seatbelt or break, and act as a projectile.

The chest clip is designed to prevent the child restraint occupant from taking the shoulder straps off their shoulders by clipping the two shoulder straps together across the chest. However, in the event of a crash, depending on how it is positions, there may be a risk of choking, strangulation, injury to the throat or chest. Use of this device may also make it more difficult or time consuming to remove a child from the vehicle in an emergency. However, without conducting dynamic testing to further understand the potential hazards of these devices, it is difficult to establish whether these theoretical risks are realistic, and hence whether devices are fit for use in a real world scenario.

Although the voluntary Australian Standard *(AS/NZ 8005) Accessories for Child Restraints for use in Motor Vehicles* was introduced in 2013 (Standards Australia, 2013), there is still very little known about whether devices meeting this standard affect the performance of a restraint detrimentally. The aim of this study was to investigate how child restraint accessories interact with a child restraint in a crash. RACV commissioned APV Tech Centre to develop a test protocol that can be used for the dynamic assessment of child restraint accessories. This protocol was subsequently used to undertake dynamic assessment of a gated buckle and chest clip to determine whether there are any potential safety implications of these devices in the event of a crash.

Methodology

There were two phases to this study. The first phase involved developing a protocol for dynamic assessment of child restraint accessories, while the second phase involved using the protocol to perform testing of two products, the gated buckle and chest clip.

Protocol development

A protocol for dynamic assessment was prepared from relevant sections of existing standards. *AS/NZS 8005:2013 - Accessories for child restraints for use in motor vehicles* (Standards Australia, 2013) was used as a base and increased performance requirements were further specified to match the Child Restraint Evaluation Program (CREP) protocol where appropriate. Other recognised standards were also used; e.g. seat belt modification devices (i.e. gated buckle) were subjected to sections of the Australian Design Rules 4/05 (Vehicle Standard, 2014) to verify the integrity of the belt would not be compromised. The protocol was reviewed by RACV Vehicle Engineers and a full protocol was finalised that will enable further testing of additional child restraint accessories to be completed independently of this research.

Gated buckle

The gated buckle was tested using a rearward and forward facing child restraint. Table 1 outlines the specific tests that were conducted, the test type, dummy type, and sled acceleration for each test. The following items were purchased for use in the testing:

- Six Babylove Ezy-Switch restraints (1754:2010 BL72C/2010) for use in the rearward facing position (mode A2).
- Six Mothers Choice Nimbus restaints (1754:2010 GS2010) for use in the forward facing position (mode B).
- Six bowed gated buckles (as shown in Figure 1).

The child restraints were specifically chosen for a number of reasons. In particular, they both performed reasonably well from a safety perspective (i.e. both scored 3 stars for safety in CREP testing), and from a consumer perspective they are reasonably priced. This suggested they may be popular choices for parents. The bowed gated buckle was specifically chosen as it appeared to be the most commonly available to the public. An online store was also able to confirm that they sold significantly more bowed gated buckles as opposed to the flat gated buckle. Additionally, RACV restraint fitters perceived the bowed gated buckle to be more effective in keeping the seatbelt tensioned the than the flat gated buckle.

Table 1. Tests conducted to assess the gated buckle.

Child restraint	Baseline /	Dummy	Test type	Sled acceleration

Direction	gated buckle	type		(km/h)
Rear facing	Baseline	TNO P1.5	Frontal	56.3
Rear facing	Gated buckle	TNO P1.5	Frontal	56.1
Rear facing	Baseline	TNO P1.5	perpendicular struck side	32.6
Rear facing	Gated buckle	TNO P1.5	perpendicular struck side	32.5
Rear facing	Baseline	TNO P1.5	66° struck side	32.8
Rear facing	Gated buckle	TNO P1.5	66° struck side	32.8
Forward facing	Baseline	TNO P6	Frontal	56
Forward facing	Gated buckle	TNO P6	Frontal	56.3
Forward facing	Baseline	TNO P3	perpendicular struck side	32.7
Forward facing	Gated buckle	TNO P3	perpendicular struck side	32.3
Forward facing	Baseline	TNO P3	66° struck side	32.5
Forward facing	Gated buckle	TNO P3	66° struck side	32.5

Figure 1. A gated buckle prior to testing

Chest clip

The chest clip was tested using a forward facing child restraint only. A rearward facing restraint was not used in this testing because the issue of a child removing their arms from a harness is most common for toddlers who are in a forward facing restraint in Australia. Additionally, the chest clips are mainly marketed towards children when in forward facing mode. Table 2 outlines the specific tests that were conducted, the test type and sled acceleration for each test. The following items were purchased for use in the testing:

- Three Houdini Stops (as shown in Figure 2)
- Six Mothers Choice Nimbus child restraints (1754:2010 GS2010) for use in a forward facing position (mode B).

The child restraint was specifically chosen for a number of reasons. In particular, it performed reasonably well from a safety perspective (i.e. scored 3 stars for safety in CREP testing) and is reasonably priced, suggesting it may be a popular choice for parents. The specific chest clip was chosen as it appears to be the most widely available device in stores within Australia, and hence the most likely to be used by parents.

Table 2. Tests conducted to assess the gated buckle.

Child restraint Direction	Baseline / chest clip	Dummy type	Test type	Sled acceleration (km/h)
Forward facing	Baseline	TNO P6	Frontal	56.3
Forward facing	Chest clip	TNO P6	Frontal	56.3
Forward facing	Baseline	TNO P3	perpendicular struck side	32.7
Forward facing	Chest clip	TNO P3	perpendicular struck side	32.3
Forward facing	Baseline	TNO P3	66° struck side	32.5
Forward facing	Chest clip	TNO P3	66° struck side	32.9

Figure 2. Packaging of the chest clip that was purchased and used for the testing

Dynamic Assessment Procedure

As specified in the protocol, a comparison of key measurements was made from tests with the accessories fitted to a series of baseline tests.

For each test the child restraint was mounted following the manufacturer's instructions to a seat fixture. The top tether adjuster and seat belt harness adjuster were both subjected to a 60-80N tensile force following the removal of slack.

Three digital high speed cameras (operating at 1000 frames per second) were utilised to capture each test. A mixture of on-board and facility mounted cameras were used. For the frontal test with the chest clip, an extra camera was added to the front left to capture head movement and potential contact with the accessory.

The sled acceleration during the pulse was measured using two accelerometers fixed at the rear of the sled then put through a Channel Frequency Class 60 (CFC60) filter compliant to Society of Automotive Engineers, SAE J211 1988 (Standards Australia, 1988). The sled velocity was measured using a raster strip mounted to the facility and two optical sensors on the sled.

During the chest clip testing, the shoulder pads were removed from the two shoulder straps of each child restraint in order to position the accessory as shown on the packaging (as no instructions on fitment height were provided). All chest clips were coated in blue and green zinc to show any interactions with the dummy. Blue zinc coated the two outer clips and green zinc coated the centre strap.

All gated buckles were fitted using the procedure provided by an RACV representative. This involved fitting the gated buckle to the retractor side of the restraint to pin the sash and lap belts together, with enough tension to fit a few fingers at the top back of the restraint, this equated to approximately 20 N through the lap belt once the gated buckle was fitted (with no occupant or weight applied).

Results

Gated Buckle

During the frontal test in the forward facing mode a small increase in forward knee travel was observed when the gated buckle was fitted. This extra movement forward is considered to have a negative effect upon occupant safety as occupant impact with the vehicle interior is more likely. However, the type or severity of any injuries resultant of such an impact is unknown.

Additionally, the use of the gated buckle was found to result in an increase in the head impact and decrease in the chest impact values during the forward facing frontal test. These results may have been influenced by the child restraint backrest twisting *more* at the top when fitted with the gated buckle, as shown in Figure 3.

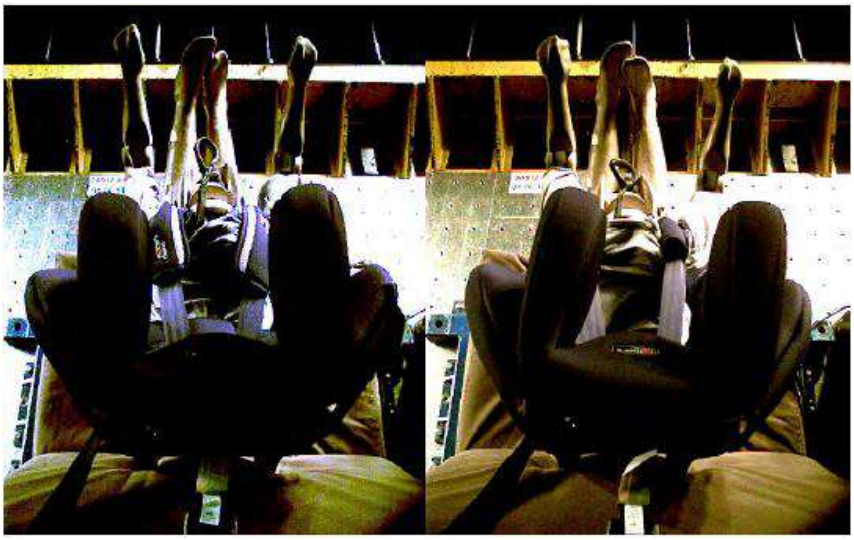

Figure 3. The backrest twisted more during the gated buckle test (right) when compared to the baseline test (left), at 96ms after impact.

Conversely when a rear facing restraint was used in the frontal test, the head impact value decreased and the chest value increased when using the gated buckle. These results may have been influenced by the restraint twisting *less* when used with the gated buckle, as shown in Figure 4.

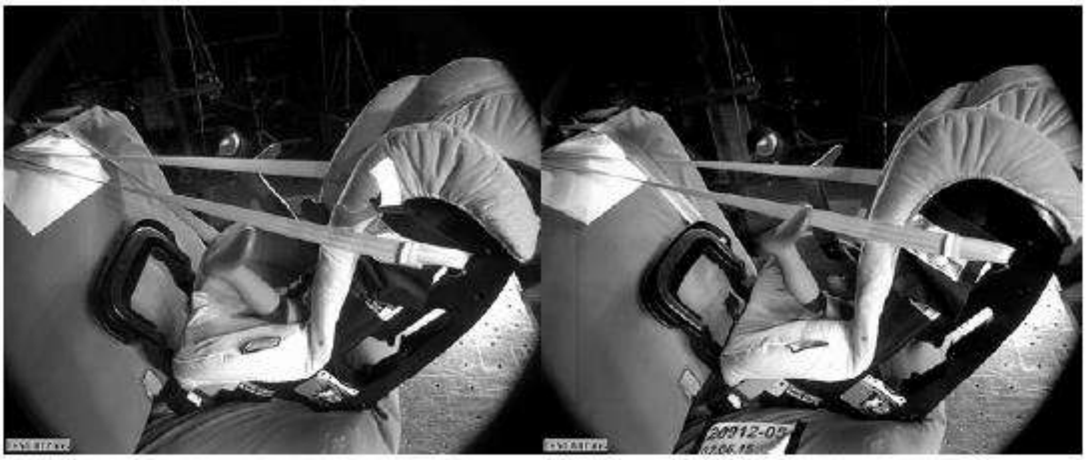

Figure 4. The restraint twisted less during the gated buckle test (right) when compared to the baseline test (left), at 96ms after impact.

These contrasting findings are also likely to be a result of a modified proportion of top tether loading vs seat belt loading.

During all side impact tests with the gated buckle, particularly in the rearward facing mode, the child restraint travelled a shorter distance and rotation was significantly reduced, predominantly after impact with the door. Due to this reduced rotation, improvements in occupant positioning within the restraint were apparent. As shown in Figure 5, the head was observed to remain within the enclosure of the child restraint for a greater period of time. This was evident for all side impact tests with the exception of the forward facing oblique test.

Figure 5. Dummy position during testing without the gated buckle (left) & dummy position during testing with the gated buckle (right)

This is considered to have a significant safety advantage as it could prevent head impact with the vehicle interior, other occupants or intrusion. Additionally, it places the occupant of the restraint in a safer position if there are to be further accelerations or impacts.

The injury results also support an outcome of positive safety benefits for side impact tests, as both head and chest injury values were found to decrease when the gated buckle was fitted for the side impact tests (with the exception of the rear facing oblique side test).

The reduced rotation during side impact tests is likely to be a result of the gated buckle providing a more laterally stiff lower mounting arrangement, which has appeared to restrict displacement and rotation of the restraint base.

Despite pre-test perceptions that the gated buckle may either break or become completely unthreaded from the seatbelt, the accessory itself remained attached for all tests. However, the webbing did become partially unthreaded during a number of tests, as shown in Figure 6. It is not known how likely it is that a gated buckle could become completely unthreaded or release webbing after or during the test. A number of gated buckles also showed significant signs of deformation following testing, an example is shown in Figure 7.

Figure 6: The gated buckle following testing, showing the partially unthreaded belt.

Figure 7. The bent gated buckle following testing.

Chest clip

Figure 8 shows the chest clip fitted prior to testing. Frontal testing found that there was an increase from a likely serious head injury (baseline test) to a likely critical head injury (accessory test). An increase in head injury of this scale was a somewhat unexpected finding, as prior to testing it was expected that the addition of the chest clip was more likely to influence the results for a chest injury in a frontal test, rather than head injury. Therefore, it is unclear how much of this variation can be attributed to the use of the chest clip alone.

Figure 8. Chest clip in position before test

It is possible that this finding is a result of a variation in the dummy's head direction and speed, which was observed to change slightly during the accessory test when compared to the baseline test. While the addition of the chest clip may have played a role in this variation, it is also believed to be in part due to the removal of the shoulder pads from the harness (which was required in order to secure the chest clip to the harness).

During the oblique side impact tests, severity of both head and chest impacts was reduced with the addition of the chest clip compared to baseline testing. The chest clip is considered to play a significant role in this finding, as the likely outcome of the chest clip holding the two shoulder belts at a set distance prevented the belt from slipping over the shoulder. It is considered vitally important if the shoulder straps are kept on the occupant's shoulders prior to an impact and this finding is considered to have positive safety implications.

At no point during any of the testing did the chest clip contact the occupant neck nor did the neck appear to move significantly towards the clip, which previous research suggested could be a risk. The chest clip also did not slip up the harness straps. However, the chest clip was observed to make impact with the face during the frontal test, which could potentially result in facial injuries. As facial injuries were unable to be measured, the type or severity of any potential facial injuries from use of these devices remains unknown.

In addition, in all tests the chest clip maintained its integrity, no items detached, and no damage was noted to the device, suggesting no parts of this device would act as a projectile in a crash. It was also able to be easily unclipped following testing. This fails to support the finding of the desktop review, which suggested damage to the device may result in difficulties removing the child from the restraint in the event of a crash. However, use of the chest clip is still likely to result in additional time removing the child from the restraint in an emergency, whether the device is damaged or not.

Discussion

While some positive safety outcomes were observed when using the gated buckle with a rearward and forward facing restraint, there are also some small safety concerns apparent, although the severity of these concerns are unknown. In particular, the way the restraint responded to the stiffness changes caused by the gated buckle appeared to reduce the restraint rotation in side impact crashes and hence improve occupant positioning during and after the crash. This was supported by a reduction of head and chest injury results when the gated buckle was fitted. On the other hand, during a frontal crash with a forward facing restraint the occupants' knees were more likely to come into contact with the interior of the vehicle, the implications of which are unknown.

The previous RACV desktop review outlined that if the gated buckle was to be used incorrectly it may allow excess slack in the lap section of seatbelt or it could also come into contact with child. Although misuse was not investigated in this particular research, the webbing was observed to become partially unthreaded during the rearward and forward frontal tests and during the rear facing oblique side impact test. It may be assumed that such a situation will have a detrimental effect on any subsequent impacts. For example, it may result in excess slack of the seatbelt or may result in the gated buckle coming completely loose and acting as a projectile in the vehicle. However, the real world consequences of this finding are unquantified. It is recommended that further tests be conducted to validate this assumption.

The gated buckle is designed to convert a lap/sash seatbelt into a lap only belt. It is generally used to provide a tight, secure installation of the child restraint and to ensure the restraint remains in the installation position throughout ongoing use. When deciding whether to use an aftermarket gated buckle consideration should first be given to the manufactures instructions. Many restraints already come with a gated buckle or have an inbuilt 'locking clip', and hence these devices should be used where recommended by the manufacturer. Consideration should also take into account how the vehicle seatbelt interacts with the child restraint system during installation. For example, if secure installation is problematic or the restraint is becoming loose over time without a gated buckle, then the use of the device may be required.

It is important to note that these results are dependent on the specific method used to fit the gated buckle. A strict installation method that is taught throughout the RACV restraint fitter network was investigated, as was the use of a particular style of gated buckle. However, it is possible that inconsistent positioning of these devices is likely by those that have not been trained in this particular method, in which case comparable outcomes may not be achieved.

The minor safety concerns identified in the frontal test with a forward facing restraint may be offset by the benefits reported in side impact crashes. For example, despite the knees being more likely to come into contact with the vehicle interior in a frontal crash, it is unknown what injuries will occur as a result. Whereas in a side impact crash, an improvement in restraint and occupant positioning was observed, suggesting improved protection particularly for the head and chest. Therefore, the findings of the current study indicate that these devices can be used with some caution, taking into account the minor risk of knee/leg injury, the benefits of improved head and chest protection, and the practicality of fitting restraints appropriately.

Earlier RACV research found that chest clips may pose a number of safety issues in the event of a crash, such as a risk of choking/strangulation; injury to the throat or chest (especially if the device is comprised of hard materials); and/or difficulties or additional time required to remove a child from the restraint in an emergency. However, the current research was unable to verify many of these concerns.

During testing the use of the chest clip appeared to result in changes to the dynamics of the dummy in a frontal crash situation. This was evidenced by the change in head direction and speed during the frontal tests. However, it is important to note that it is unlikely that the chest clip alone influenced this change. It is possible that the removal of the shoulder pads between the baseline and accessory tests was also a significant factor in this variation.

Additionally, because the baseline test found that a likely serious head impact already existed with the use of this particular restraint, these results may not be representative when using a chest clip with other restraints that do not already have the existing head injury during a baseline test. Further testing should be undertaken to validate such assumptions.

There appeared to be some safety benefit of using the chest clip in the event of a side impact crash, which was evidenced by the chest clip assisting the harness to remain on the dummy's shoulders. This is considered to result in better occupant retention within the restraint. Any consequences of having the occupants shoulders free of the harness during a crash are unknown. It is considered vitally important that the shoulder straps are kept on the occupants shoulders prior to an impact, so in circumstances where children are regularly removing the harness from their shoulders the chest clip may be a benefit while this behaviour persists.

The chest clip is an aftermarket device that is intended to prevent the child restraints occupants from taking the shoulder straps off their shoulders at the incorrect time (e.g. during travel). When determining whether the chest clip is to be used, it should first be ensured that the harness straps are appropriately tightened and the restraint is being used correctly. Consideration should then be a compromise between preventing the occupant wriggling out from the restraint; fitting the device so contact with the neck is avoided (includes being mindful of the potential that misuse may result in neck contact during any impacts); and ensuring contact with the face is avoided in the event of a frontal crash. It is also worth carefully considering the added step of needing to remove the device in the event of an emergency, as it may not be the parent or even an adult removing the child from the restraint and unfamiliarity with the device may result in unnecessary complications.

Conclusion

The current research focused on correct use of two child restraint accessories, the gated buckle and the chest clip. Future research may benefit from considering the safety implications of misusing these devices. Additionally, as two devices were able to be tested in the current research, follow up research may consider assessing how other types of accessories influence the safety implications of child restraints. Furthermore, in a similar style to CREP, there may be some benefit in comparing different variations of the same type of accessory and providing a rating from a safety perspective. For example, comparing a bowed style gated buckle with the flat style gated buckle.

Future research may also benefit from including a strict dummy positioning process or dimensional verification using a 3D measuring device prior to each test, which would minimise unintended variations from baseline tests.

This research has assisted in providing better knowledge on the safety of the gated buckle and chest clip device. However, there are many other child restraint accessories available on the market. Additionally, there are also many different variations of the same device. The protocol developed in the current study has been created with these other devices in mind, and can similarly be used to assess safety implications of other products.

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Improving Road Safety Barrier Effectiveness: Issues and Opportunities

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Abstract

A key element of the Safe System approach is safer roads and roadsides. Roadside safety interventions commonly default to road safety barrier installations to shield hazards; due to budget limitations and constrained road reserves. But the significant safety benefits possible through advances in barrier hardware technology and improvements in the understanding of design have not been fully realised. Achieving fit for purpose installations continues to challenge the capabilities of the roading infrastructure industry. The emerging challenge will be to meet the aspirations of the road controlling authorities through improving road safety barrier design, specification and installation.

The likelihood of sophisticated barrier hardware performing as designed, tested and accepted becomes increasingly questionable as the installation conditions vary from those that were tested. A survey of legacy road safety barrier systems in New Zealand provides some guidance in the development of a strategy to advance the general improvement in road safety barrier design, hardware specification and installations towards improving roadside safety.

There are a number of systemic challenges facing industry that need to be addressed to get the most out of the investment in road safety barriers. These include:

- implementing the most effective compliance regime,
- accepting compliant hardware and moving away from legacy hardware that cannot achieve compliance,
- developing a certification regime for both designers and installers.

This paper reviews issues and opportunities to achieving improved road safety barrier installations.

Introduction

A key element of the Safe System approach is safer roads and roadsides (New Zealand Road Safety Strategy 2010-2020). A safe road system is one where drivers rarely leave the road; but when they do, the vehicle and roadside are both designed to help protect vehicle occupants from death or serious injury. Roadside safety interventions commonly default to road safety barrier installations to shield hazards. This is often due to the higher costs of other interventions such as removal of the hazard.

A legacy of road safety barrier systems exists on the New Zealand State Highway network. The majority of these have been installed through the last 50 years. Current performance expectations have continually evolved through a greater understanding of how road safety barrier systems contain and redirect impacting vehicles. Consequently, most of the older legacy systems will have been designed and installed without the benefit of the more recent knowledge, and consequent performance standards and hardware. In 1999 the New Zealand Transport Agency (then Transit New Zealand) adopted the United States Federal Highway

Administration National Cooperative Highway Research Program (NCRHP) 350 test regime to ensure that all new installation hardware met reasonably robust performance standards.

The likelihood of barrier hardware performing as designed, tested and accepted becomes increasingly questionable as the installation conditions vary further from those that were tested. As technical advances in barrier hardware and design have not been well understood by practitioners significant faults that will affect performance continue to be common place.

The New Zealand Transport Agency (NZTA) undertook this study to provide a more informed assessment of the nature and size of the potential performance liability of legacy systems. This information would then to be used in the development of network safety management strategies. These strategies could include industry training to increase capability amongst those involved in the design, installation, and maintenance of road safety barrier systems.

Scope of Research Study

Highway segments were selected to be representative of the rural two lane State Highway network. This was to enable the findings to be used more broadly in the development of a network strategy. A sample of State Highway road safety barrier installations on those segments were assessed to broadly gauge overall crash performance risk. The surveys were undertaken in June 2010. The road safety barrier installations were drawn from:

- Napier Region: State Highway 2 – Woodville to Hastings
- Tauranga Region: State Highway 2 – SH33 to Matata
- Tauranga Region: State Highway 2 – Athenree to Katikati.

This risk assessment was derived through the identification and gauging of design, installation or maintenance deficiencies. The deficiencies were categorised based on an assessment of their potential contribution to a crash outcome, as being minor, significant or serious. The aggregate risk assessment for each installation was deemed to be that of the worst deficiency.

Significant or serious design and installation deficiencies were generally attributable to inadequate length of need, inadequate approach grading and clear areas at end treatments. On older installations, this often will be a reflection of how the understanding of crash performance has progressively improved since their installation. An end treatment that was appropriate when installed many years ago may not be compliant with current performance standards.

However it may be that more recent installation problems are a consequence of a poor understanding of not only how a barrier system operates during an impact, but also what the implications are of not achieving the design and test conditions. For example, inadequate approach grading can potentially result in an impacting vehicle not engaging an end terminal properly, with a poor crash outcome.

Poor routine maintenance could potentially compound design and installation deficiencies. In the event of an appreciable impact, those installations with significant or serious maintenance deficiencies could potentially experience a system failure, and consequently a poor crash outcome.

On completion of the surveys, common deficiencies were categorised as design, installation, or maintenance issues and assigned relative treatment priorities.

Survey Methodology

Survey procedures were developed to readily identify the deficiencies and grade the associated risks. The procedures are a screening tool rather than a substitute for the more detailed fit for purpose inspections. The screening enables the road controlling authority or network management consultant to identify those locations where more detailed, specialised assessments may be warranted.

Barrier installations were inspected along the selected representative highway lengths. Surveys were not done at locations where they could not be undertaken safely without additional positive temporary traffic management measures. Reasons for this included the lack of shoulder and verge width for positioning the survey vehicle, inadequate sight distance, or a limited ability to do most of the survey work from behind the barrier. As these locations accounted for less than 30% of the total number of sites on the surveyed highway lengths, the results are on balance representative.

The assessments for each location included:

- General
  - Leading end location reference.
  - An indicative assessment of age to nearest 5 years.
  - Hazard description that required the barrier system.
  - Overall length estimate to nearest metre.
- Design
  - An indicative assessment of the length of need.
  - An indicative assessment of the clear area at the ends of the barrier.
  - An indicative assessment of the appropriateness of the installed end treatment.
- Installation
  - An indicative assessment of the end treatment installation including compliance with current performance standards, applicable supplier or agency installation guidelines and delineation.
  - An indicative assessment of the installation of the barrier to the mid-length of the installation including height, rail and post condition.
- Maintenance
  - An indicative assessment of the general condition and outstanding routine maintenance that could affect performance.

Assessment Criteria

Overview

Austroads has produced a list of common roadside hazard types, including barriers, with relative crash severities (Austroads Guide to Road Design Part 6: Roadside Design, Safety and Barriers, 2009). Roadside features such as poles, trees and cliffs represent significant hazards to vehicles that leave the roadway. Although the installation of barriers will generally reduce this risk, poorly designed or installed barriers could negate any risk reduction. This is particularly the issue when these deficiencies are associated with end terminals that are in crash prone or high risk locations.

Poor installation and maintenance of a barrier system can lead to snagging or pocketing of an impacting vehicle and, ultimately, rupture or override of the barrier. Whereas, inadequate length of need indicates that the length of barrier is unlikely to be sufficient to prevent an errant vehicle from impacting a roadside hazard rather than reflecting the likely impact performance of the barrier itself. Similarly, inadequate approach grading can also potentially result in an impacting vehicle not engaging an end terminal properly.

A suitable survey assessment methodology for barrier installations was not found. Consequently, indicative evaluation criteria were developed by the surveyor to enable the simplified assessment of the installations. These criteria are fundamentally relative measures, whereby the further a particular element is out of the norm the greater the significance and relative risk. They are not precise and were used only as a coarse gauge in assessing an installation. The grading criteria for the generalised deficiencies are summarised in the following sections:

Design

- Length of Need: Measure = length deficiency

Risk	**Percent**
Minor	< 25
Significant	25 - 50
Serious	> 50

- Clear Area: Measure = length or width deficiency

Risk	**Percent**
Minor	< 25
Significant	25 - 50
Serious	> 50

- Barrier System Selection

Risk	**Description**
OK	Compliant – Optimal Choice
Significant	Compliant – Sub Optimal Choice
Serious	Compliant – Incorrect Choice
Serious	Non-Compliant

Installation

- Height: Defined by worst condition.

Risk	**Height**
OK	Within +/- 20mm
Significant	Outside +/- 20mm But Within +/- 50mm
Serious	Outside +/- 50mm

- Installation Errors: Defined by worst condition.

Risk	Description
Minor	Incorrect or Missing Delineation
M/S/S	Approach & Clear Area Grading Deficiency
M/S/S	Fill Support Behind Posts Deficiency
Serious	Incorrect Bolting
Serious	Missing Components

Where M/S/S is Minor or Significant or Serious.

Maintenance

Defined by worst condition.

Risk	Description
Minor	Impact Head Droop
Significant	Loose Anchor Cable
Significant	Post Condition 5/10 to 7/10
Serious	Post Condition < 5/10
Serious	Broken Components (e.g. posts)
Serious	Blocked Impact Head

Relative Priority

The relative priority to address the deficiencies was also estimated including:

- Priority 1 (P1) refers to a deficiency or condition that can either be easily corrected or is fundamental to the safe operation of the barrier system, or both. Examples would be missing or loose anchor cables, or an impact head that is blocked by detritus.
- Priority 2 (P2) represents a more generalised deficiency such as a significant or serious height variation, which would best be addressed through an area wide treatment.
- Priority 3 (P3) represents a more extensive intervention that would effectively result in the complete redesign and installation of the system. An example of this would be a significant or serious shortfall of the length of need requirement.

The priority was adjusted where a higher risk issue would require attention sooner. For example a serious length of need deficiency that would generally have required Priority 3 action that also included a non-compliant terminal was raised to a Priority 2.
In addition, absent or incorrect delineation was rated as a minor installation deficiency. However, that rating was given a higher rank when the corrections of design or installation deficiencies were not likely to occur in the short term. Delineation becomes more important in that situation, as the ongoing exposure of traffic to these end treatment hazards requires that they at least be warned of their danger.

Survey Results

Overview

The basic survey results for the installations are presented in Appendix A. The development of management strategies to address the problem requires an understanding of the type and extent of these faults. Consequently, the faults were further aggregated for comparison, and inferences drawn that could lead to a range of management interventions. A summary of the significant and serious deficiencies are summarised in Table 1.

Table 1: Significant and Serious Deficiencies Summary

	Napier	Tauranga	Total	Total %
Design				
LoN	26/40	37/40	63/80	79
Clear Area	24/40	23/40	47/80	59
Selection	11/40	20/40	31/80	39
Installation				
Terminals	34/40	35/40	69/80	86
Barrier	29/40	40/40	69/80	86
Maintenance				
Terminals	23/40	35/40	58/80	73
Barrier	2/40	15/40	17/80	21

Deficiency Patterns

Deficiency patterns were broken down by the estimated age of the installations. In those cases where there had been significant work more recently, an estimate of the latest intervention age was made. Tables 2 and 3 summarise the significant and serious deficiencies by age.

Table 2: Napier Significant and Serious Deficiencies - Percentage by Age

Years	**< 5**	**5-10**	**10-15**	**15-20**	**> 20**
Design					
LoN	15	54	8	19	4
Clear Area	13	54	8	17	8
Selection	18	18	0	46	18
Installation					
Terminals	12	47	18	18	5
Barrier	10	45	21	17	7
Maintenance					
Terminals	13	61	13	13	0
Barrier	0	0	100	0	0

Table 3: Tauranga Significant and Serious Deficiencies - Percentage by Age

Years	**< 5**	**5-10**	**10-15**	**15-20**	**> 20**
Design					
LoN	19	22	8	27	24
Clear Area	13	18	4	35	30
Selection	5	0	5	55	35
Installation					
Terminals	14	17	14	52	3
Barrier	20	20	13	40	7
Maintenance					
Terminals	13	6	26	46	9
Barrier	13	13	7	47	20

Generally, the deficiency patterns between the Napier and Tauranga surveys were similar for the newer installations less than 5 years. However, the design and installation deficiencies were more pronounced in the 5 to 10 year range in Napier, compared to the 15 to 20 year range for Tauranga. These could for example be due to a change in network managers or contractors.

The maintenance issues related to terminals reflect the characteristics of the terminals installed in those age brackets. Issues with the 15-20 year old end treatments in Tauranga relate to non-compliant end terminal installations. Generally, these have also not been maintained routinely. The more recent Napier terminal maintenance faults are predominately loose anchor cables, particularly in the 5 to 10 year old range.

Interpretation of Findings

A barrier system can have deficiencies that fall into any combination of the design, installation or maintenance categories, for either of the end treatments or the barrier system. The deficiencies are not mutually exclusive, in that an overall installation could have a combination of deficiencies and locations.

The design and installation issues found in older systems are likely a consequence of being completed when barrier design and performance was less well understood. Similar problems found in more recent installations suggest that design and installation quality processes are failing to achieve acceptable installations.

Most of the road safety barrier installations surveyed had significant or serious deficiencies that could affect their performance and consequently the crash outcome. There were no installations that had no significant or serious deficiencies.

Between 60% and 80% of the surveyed installations had design deficiencies due to inadequate length of need or safety clear area. About 40% of installations had non-compliant or inappropriate end treatments. The inappropriate end treatments were generally legacy systems such as BCT treatments used in leading end applications. Most of these would have been installed long before the current performance standards were developed and adopted.

About 86% of the surveyed installations had significant or serious installation deficiencies. However, most installation deficiencies are readily repairable. Typically these include end treatment issues associated with height, grading, or missing or incorrect terminal bolting patterns.

About 75% of installations had issues relating to outstanding end treatment maintenance, and about 20% of installations had barrier maintenance issues. Most of the significant and serious maintenance issues could be easily identified and remedied. Typical examples include anchor cable tightening. It could be that network managers or contractors were not trained to identify appropriate maintenance issues, or are avoiding contractual obligations.

Conclusions and Recommendations

The following recommendations would contribute towards addressing the various road safety barrier legacy issues identified, help to raise industry capability and help to improve the quality of future barrier installations. They need not proceed together as some may require more immediate action, while others will take longer to initiate and should be considered with other roadside safety priorities. The recommendations are:

- General
  - Adopt the road safety barrier compliance regime that most effectively represents the vehicle fleet distribution.
  - There should be no further installations of non-compliant hardware. At risk non-compliant legacy hardware installations should be programmed for replacement relative to risk.
  - Establish performance measures in design, installation, and maintenance contracts to reflect progress towards achieving road safety barrier quality assurance system, deficiency databases, and the monitoring and reporting of progress.
  - Develop an industry training regime that addresses design, installation, and maintenance issues.
- Design
  - Develop a quality assurance regime based on having appropriately trained people responsible for approving the design and installation of barrier systems. The quality assurance system should include an audit program for design, installation and maintenance areas.
  - Develop and disseminate standard plans for typical design and installation details (e.g. transitions and curved rail end treatments).
  - There is a large proportion of existing systems that have inadequate length of need, clear area, or have non-compliant terminal ends that will require funding to address. On balance most of the serious and significant risk installations will effectively require replacement, given the extent of the faults.
- Installation
  - Develop a road safety barrier installation and maintenance manual to cover the identification, installation and maintenance checklists for common barrier hardware.
  - Have the maintenance consultant assess all installations and develop a prioritised deficiency database. The redress of legacy design and installation deficiencies older than existing contacts would likely require program funding, as it could be outside the scope of current maintenance contracts.

  - All installation deficiencies that can be readily addressed (e.g. incorrect bolting patterns, missing bolts, delineation and grading) should be remedied when addressing routine maintenance deficiencies.
- Maintenance
  - Have all maintenance contractors review their current barrier inventory, noting that they are required to *maintain the barriers in a condition fit for purpose.*
  - Changes should be made to contract documents to reinforce the need for routine rather than random maintenance, at least to the same level of emphasis as barrier repairs are now covered in these documents.
  - Audit the inventory and use whatever sanctions are available to achieve the intended purpose of having all installations fit for purpose. All installations should be routinely maintained to standard, irrespective of whether they have design or installation issues that cannot be readily addressed.

Further, as a large proportion of this aging infrastructure nears the end of its life cycle, costly replacements will need to be considered and programmed. Replacements will generally involve more extensive installations to meet the higher levels set out in current standards.

The development of retrofit or replacement programs will need to be considered in the context of overall roadside safety protection and improvement priorities. The cost effectiveness of improvements to road safety barrier legacy systems must be balanced not only with that of new barrier installations, but also with those of other safety interventions.

References

New Zealand Ministry of Transport, New Zealand's Road Safety Strategy 2010-2020, 2010.
Austroads Guide to Road Design Part 6: Roadside Design, Safety and Barriers, 2009.

Appendix A

Plate A1: Road Safety Barrier Legacy Survey Deficiencies – Napier

ROAD SAFETY BARRIER LEGACY SURVEY - NAPIER SUMMARY JUNE 2010

				DESIGN		INSTALLATION		MAINTENANCE	
Location		Age (years)	LoN	Clear Area	Terminal	Terminal	Barrier	Terminal	Barrier
Napier 1	- Leading	10 to 15	significant	significant	OK	serious	serious	serious	OK
	- Trailing	10 to 15	serious	serious	OK	significant	serious	OK	OK
Napier 2	- Leading	20 +	serious	serious	serious	serious	serious	OK	OK
	- Trailing	<10 & 20 +	serious	serious	significant	serious	serious	OK	OK
Napier 3	- Leading	< 10	OK	serious	OK	serious	OK	OK	OK
	- Trailing	< 10	NA	significant	OK	serious	OK	OK	OK
Napier 4	- Leading	< 10 & 10 to 20	OK	significant	OK	OK	serious	OK	OK
	- Trailing	< 10 & 10 to 20	significant	OK	OK	minor	serious	OK	OK
Napier 5	- Leading	< 5	serious	OK	OK	OK	OK	OK	OK
	- Trailing	< 5	serious	OK	OK	significant	significant	significant	OK
Napier 6	- Leading	15 to 20	serious	serious	serious	serious	minor	serious	minor
	- Trailing	15 to 20	NA	serious	OK	serious	serious	serious	OK
Napier 7	- Leading	< 10	NA	serious	OK	serious	OK	serious	OK
	- Trailing	< 10	serious	serious	OK	serious	OK	serious	OK
Napier 8	- Leading	10 to 15	OK	OK	OK	serious	significant	OK	significant
	- Trailing	10 to 15	NA	OK	OK	serious	significant	OK	significant
Napier 9	- Leading	< 10	serious	OK	OK	OK	serious	serious	OK
	- Trailing	< 10	serious	OK	OK	minor	serious	serious	OK
Napier 10	- Leading	15 to 20	serious	significant	serious	serious	significant	OK	minor
	- Trailing	15 to 20	serious	serious	serious	serious	significant	OK	minor
Napier 11	- Leading	< 10 & 20 to 25	serious	minor	OK	significant	significant	OK	OK
	- Trailing	< 10 & 20 to 25	serious	minor	OK	significant	significant	serious	OK
Napier 12	- Leading	> 20	NA	serious	significant	serious	significant	serious	OK
	- Trailing	< 10	serious	serious	serious	serious	significant	OK	OK
Napier 13	- Leading	< 5	serious	serious	serious	serious	OK	OK	OK
	- Trailing	< 5	NA	significant	serious	serious	significant	serious	OK
Napier 14	- Leading	< 5	NA	significant	OK	serious	significant	serious	OK
	- Trailing	< 5	serious	OK	OK	minor	OK	serious	OK
Napier 15	- Leading	10	NA	serious	OK	serious	minor	serious	OK
	- Trailing	10	serious	serious	OK	serious	OK	serious	OK
Napier 16	- Leading	< 10	serious	serious	OK	serious	significant	serious	OK
	- Trailing	< 10	serious	serious	OK	serious	significant	serious	OK
Napier 17	- Leading	< 10	serious	serious	OK	serious	serious	serious	OK
	- Trailing	< 10	NA	serious	OK	serious	serious	serious	OK
Napier 18	- Leading	10 to 15	NA	OK	OK	serious	significant	serious	OK
	- Trailing	10 to 15	NA	minor	OK	serious	significant	serious	OK
Napier 19	- Leading	15 to 20	serious	OK	serious	serious	serious	OK	OK
	- Trailing	15 to 20	serious	OK	serious	serious	serious	serious	OK
Napier 20	- Leading	< 10	significant	OK	OK	serious	OK	serious	OK
	- Trailing	< 10	serious	OK	OK	serious	significant	serious	OK

Priority 1
Priority 2
Priority 3

Plate A2: Road Safety Barrier Legacy Survey Deficiencies – Tauranga

ROAD SAFETY BARRIER LEGACY SURVEY - TAURANGA SUMMARY JUNE 2010

			DESIGN			INSTALLATION		MAINTENANCE	
Location		Age (years)	LoN	Clear Area	Terminal	Terminal	Barrier	Terminal	Barrier
Tauranga	1 - Leading	20	serious	OK	serious	significant	significant	serious	significant
	- Trailing	20	serious	serious	serious	serious	significant	serious	serious
Tauranga	2 - Leading	20 to 25	serious	serious	serious	serious	serious	serious	serious
	- Trailing	20 to 25	serious	serious	serious	serious	significant	serious	serious
Tauranga	3 - Leading	20	serious	serious	serious	serious	serious	serious	significant
	- Trailing	20	serious	serious	serious	serious	significant	serious	significant
Tauranga	4 - Leading	20+	serious	OK	serious	serious	serious	serious	serious
	- Trailing	15	serious	OK	serious	serious	serious	serious	serious
Tauranga	5 - Leading	< 5 & 10 to 20	serious	OK	OK	serious	serious	serious	serious
	- Trailing	< 5	serious	serious	OK	serious	significant	minor	serious
Tauranga	6 - Leading	10	serious	significant	OK	serious	serious	significant	OK
	- Trailing	10	serious	OK	serious	serious	serious	serious	serious
Tauranga	7 - Leading	15	serious	serious	serious	serious	serious	serious	OK
	- Trailing	15	NA	NA	significant	serious	serious	serious	OK
Tauranga	8 - Leading	15 to 20	serious	serious	serious	serious	significant	serious	OK
	- Trailing	15 to 20	serious	serious	serious	serious	serious	serious	significant
Tauranga	9 - Leading	15 to 20	serious	serious	serious	serious	serious	serious	significant
	- Trailing	15 to 20	serious	OK	serious	serious	serious	serious	OK
Tauranga	10 - Leading	< 5	NA	OK	serious	serious	significant	serious	OK
	- Trailing	< 5	serious	significant	OK	minor	significant	serious	OK
Tauranga	11 - Leading	< 5	serious	serious	OK	OK	serious	serious	OK
	- Trailing	< 5	serious	OK	OK	serious	significant	serious	OK
Tauranga	12 - Leading	10	serious	OK	OK	serious	serious	serious	OK
	- Trailing	10	serious	significant	OK	serious	significant	serious	OK
Tauranga	13 - Leading	10	serious	serious	OK	serious	significant	serious	OK
	- Trailing	10	serious	serious	OK	serious	significant	serious	OK
Tauranga	14 - Leading	< 10	significant	OK	OK	minor	significant	minor	significant
	- Trailing	< 10	serious	minor	OK	minor	significant	minor	OK
Tauranga	15 - Leading	< 5	serious	OK	OK	minor	significant	OK	OK
	- Trailing	< 5	serious	minor	OK	significant	significant	minor	OK
Tauranga	16 - Leading	15 to 20	serious	minor	OK	significant	significant	significant	OK
	- Trailing	15 to 20	serious	OK	OK	serious	significant	serious	serious
Tauranga	17 - Leading	15 to 20	OK	OK	serious	serious	serious	serious	OK
	- Trailing	15 to 20	serious	serious	OK	significant	significant	serious	OK
Tauranga	18 - Leading	15	serious	significant	OK	serious	significant	serious	OK
	- Trailing	15	serious	serious	serious	serious	significant	serious	OK
Tauranga	19 - Leading	15 to 20	serious	serious	serious	serious	significant	serious	OK
	- Trailing	15 to 20	serious	serious	serious	serious	significant	serious	OK
Tauranga	20 - Leading	20	serious	serious	OK	serious	significant	serious	OK
	- Trailing	20	serious	significant	OK	serious	serious	serious	OK

Priority 1
Priority 2
Priority 3

Motorcycle protective clothing: physiological and perceptual barriers to its summer use

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Abstract

Despite strong evidence of protective benefits, thermal discomfort is a key disincentive to motorcyclists wearing protective clothing in hot conditions. This paper presents some findings from our studies concerning the thermal management properties of motorcycle protective clothing and their physiological impact in hot conditions.

The thermal and vapour permeability and abrasion resistance properties of motorcycle protective clothing were investigated in laboratory tests. The physiological and cognitive impact on humans was investigated using objective and subjective measures under controlled climate conditions and in a real-world riding trial. The aims were to determine: (i) if associations existed between thermal management and the abrasion-resistance properties of a range of commonly available, all-season motorcycle protective suits, (ii) the extent of the thermal load imposed by motorcycle clothing worn in average Australian summer conditions, and (iii) the impact of that thermal burden on psychophysical function.

The results demonstrated significant physiological strain for motorcyclists wearing protective clothing in hot conditions. Wide variations in the thermal characteristics and abrasion resistance properties of the suits tested were identified. Ongoing work is investigating the impact that elevated thermal discomfort and physiological thermal strain can have on riding performance and the potential for clothing features, such as ventilation ports to reduce thermal discomfort. These results will determine thresholds for the thermal qualities of motorcycle clothing required for an acceptable compromise between user comfort and injury protection. The outcome will inform industry and consumer information programs about the performance required of motorcycle protective clothing suitable for use in hot conditions.

Introduction

Protective clothing can induce heat strain by trapping metabolic heat with potentially severe consequences for physiological and cognitive function (Faerevik and Reinertsen 2003, Caldwell et al. 2006). Thermal discomfort has also been identified as a key disincentive and potential risk for motorcyclists wearing protective clothing in hot conditions (EEVC 1993, de Rome et al. 2011a, de Rome et al. 2011b). This paper presents a summary of findings from a series of three studies into the thermal management properties of motorcycle protective clothing and their physiological impact in hot conditions.

Method

The first study explored the thermal comfort properties of motorcycle clothing commonly worn in Australia and investigated the association between the thermal and abrasion resistance properties. The second investigated the physiological and cognitive impact on humans wearing motorcycle clothing under controlled climate conditions (de Rome *et al.* (in press)). Thirdly we examined the impact of motorcycle clothing under different riding conditions in a real-world riding trial.

Study 1. Ten sets of all-season motorcycle protective jackets and pants were selected to represent a range of those most commonly worn in Australia. Their thermal properties were tested using a thermal, sweating manikin in a climate controlled chamber. Thermal resistance (I_T) was tested at ambient temperature 30°C (45% relative humidity), vapour resistance (R_{eT}) was tested at 35°C(40%) (ASTM F1291-10 2010). Ensembles were tested with optional winter liners removed but ventilation ports closed. The results were used to calculate the relative vapour permeability indices (I_m) of these ensembles ($I_m = K.I_T / R_{eT,}$), where K is a constant (60.6515 Pa/K). A low permeability score indicates a garment is more likely to induce physiologically significant heat strain when worn in hot conditions. The ensemble with the lowest permeability score (I_m=0.09) was selected for use in Study 2. The ensembles were also tested for impact abrasion resistance, measured as time in seconds to hole, using a moving abrasive belt calibrated to the specifications of the European Standard for motorcycle protective clothing (CEN 2002). Results are reported descriptively. Scores for impact abrasion and vapour permeability were graphed to identify any trends in association between protective performance and thermal comfort.

Study 2. Human trials were conducted in a controlled climate (chamber) to simulate motorcycle riding in an Australian summer. Ambient temperature was *based on the range from 14th to 86th percentile average summer temperatures in Australia's seven largest cities.(BOM 2014) Temperatures were* set at 25°C (Trials A, B), 30°C Trial C and 35°C Trial D(BOM 2014). Relative humidity was 40% for all trials. Radiant heat was provided by three 500-W infra-red lamps suspended above the participant. Wind speed was simulated by a fan with velocity 30 km.h^{-1}. This study used a repeated measures design with the 12 participants acting as their own controls. They each completed four 90-min trials over four weeks, comprising one control trial (A) and three experimental trials (B, C, D). Participants were dressed identically to the manikin using the ensemble selected from Study 1 in the three experimental trials, and street clothes (jeans, long-sleeved t-shirt) in the control state. In all conditions they wore helmet, gloves and boots. The ventilation ports in the experimental garments were closed to ensure participants were tested under conditions where motorcycle clothing was most likely to disturb thermal homoeostasis. Heart rate, deep-body temperature (auditory canal) and skin temperature were continuously monitored. Self-reports of thermal and skin wetness sensation and discomfort were collected at regular intervals. Sweat rates, clothing moisture retention and evaporation rates were determined by weighing all garments before and after each trial. Results in the full paper are presented as descriptive parameters and comparisons conducted using paired t-tests and two-way ANOVA.(de Rome *et al.* 2015)

Study 3. Volunteer riders (N=22) wearing their own motorcycle protective clothing, were randomly assigned to one of two routes devised to represent 90-min. urban commuter rides or recreational rural rides in March 2015. Riders' reports of thermal and skin wetness sensation and discomfort (Gagge *et al.* 1967) were recorded at two pre-determined 5-minute rest stops. Skin temperature and humidity inside clothing was monitored continuously throughout the rides using sensors attached to the skin. Computer-based cognitive tests of reaction-time and executive function, measures of workload -Raw Task Load Index –(RTLX) (Byers J.C. *et al.* 1989)) and mood -Visual Analogue Mood Scale (VAMS)(Bond and Lader 1974) were conducted pre- and/ or post-ride. Results were analysed using SAS Mixed procedure for repeated measures.

Results

Study 1. Thermal (I_T) resistance averaged 0.36(SD:0.05) and vapour resistance (R_{eT}) averaged 140.7(SD:68.3), with only a moderate correlation between the two measures (r=0.53). The ensemble with the lowest vapour permeability (I_m=0.09) was then tested in Study 2. Eight of the ten suits failed to achieve the minimum impact abrasion resistance (4 sec.) in Zones 1 and 2 as required by the European Standard (CEN 2002). Comparison of abrasion resistance and vapour permeability index scores showed no clear pattern for jackets, but the pants with the highest abrasion resistance were also those with highest vapour permeability.

Study 2. Trials A and B were conducted at 25ºC. While body core temperature remained stable, heart rate, skin temperature and sweat production all increased significantly. In trial B, participants reported feeling hotter, more sweaty and less comfortable than in Trial A (<0.05). In fact, sweat production had doubled and whereas all sweat had evaporated in Trial A, only 60% evaporated in Trial B, leaving 40% of trapped with the clothing. The substantial physiological differences between Trial A and B are attributable to the difference between street clothes and motorcycle clothes.

There were also significant increases in physiological measures between each of the experimental trials (B-D) and the control trial. Heart rate and skin temperature increased significantly ($P<0.05$) from trials B to D. As the ambient temperature approached core body temperature, dry heat loss from the skin was reduced and body-body temperature increased.

Study 3. The average ambient temperature during the road trial was unexpectedly cool, 21ºC with 37% relative humidity. Those riding the urban route were slightly warmer (25.7ºC versus 25.5ºC, P=0.005) and wetter (42.4% versus 40.9% P=0.06) than those on the rural route. Subjective ratings of thermal sensation were consistent with measured skin temperature (P=0.004) but ratings of thermal discomfort were not (P=0.76). Subjective ratings of wetness sensation (P=0.001) and wetness discomfort (P=0.04) were consistent with humidity measured within the clothing.

Compared to rural riders, urban riders experienced greater workload (3.5 versus 2.4, P<.0001), felt less alert (37.4 versus 26.0, P<0.05) and less contented (19.3 versus 13.8, P<0.05) on completion of the ride. .

Discussion

These studies provide the first objective measures of the thermoregulatory performance of the protective clothing worn by a high proportion of Australian riders. The results have demonstrated significant potential for physiological strain for motorcyclists wearing protective clothing in hot conditions. The critical threshold occurs when the air temperature exceeds skin temperature thereby preventing dry heat losses. Beyond that point, riders must rely wholly upon evaporative cooling which may be restricted by clothing.

The on-road trial demonstrated the importance of vapour permeability even in cool weather. In addition to the differences in thermal comfort observed between urban and rural riders, the differences in workload and mood is also of interest. Those routes were selected primarily in order to explore differences in wind cooling effects between low and higher speed riding. These results suggest that the complexity of urban riding may place higher physiological demands on riders than less complex but higher speed rural roads. Further work is required to investigate the features of urban versus rural riding environments and their impact of rider fatigue and mood as a potential factor in crashes.

The results also suggest that subjective ratings of thermal and wetness sensation, if not comfort, may be valid and less costly instruments for assessing thermal comfort for studies where more precise instruments are not viable. The wide variation in thermoregulatory performance between garments suggests that thermal comfort can be improved. Comparison of the results for vapour permeability and the abrasion resistance of the pants tested also indicate that improvements in thermal comfort need not be at the expense of safety.

Ongoing work aims to establish the effectiveness of clothing features such as ventilation ports on thermal discomfort. The next stage will investigate the impact that thermal discomfort and thermal strain may have on riding performance. The results will determine thresholds for the thermal qualities of motorcycle clothing required for an acceptable compromise between user comfort and injury protection. The outcome will inform industry and consumer information programs about the performance required of motorcycle protective clothing suitable for use in hot conditions.

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Worker views on safety at roadworks

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Abstract

Roadworks in live traffic environments are hazardous to workers and road users alike. In an increasing body of international research literature, roadwork risks and hazards have been comprehensively examined. As in the broader field of road safety research, much of the work rightly takes a quantitative approach to assessing risk and related issues and to addressing the identified risks appropriately. In Australia, however, limited official data constrains the ability of researchers to achieve an in-depth understanding of the situation at state/territory and national levels based on traditional quantitative analyses. One way to enhance and supplement the limited available data is to consult those who are directly involved in roadworks for qualitative information, although such an approach is rarely reported in the roadwork safety arena. As part of the major study focusing on safety at roadworks in Queensland, 66 workers were interviewed about their perceptions and experiences regarding roadwork safety. This paper thus outlines a qualitative examination of workers' perceptions of the causes of roadwork incidents and the effectiveness of hazard mitigation measures. Consistent with findings reported in the literature is the view among workers that speeding is a major hazard and that police enforcement is the most effective countermeasure. Other hazards commonly observed by workers but less frequently reported elsewhere include driver distraction and aggression toward workers, working in poor weather and working at night. Workers mostly suggested educational measures to address distraction and aggression issues, though such measures are only tentatively supported in the literature.

Introduction

Workers and motorists are at heightened risk of injury due to the need to accommodate live traffic through roadwork sites. Crash rates on a given road section are typically elevated during roadworks compared with pre-work periods, while crash severity is often also higher. Much of this is known from the international literature, but the situation in Australia is difficult to quantify due to problems with obtaining accurate and reliable data. In Queensland, for example, crashes at roadworks are only reported in official crash data if the roadworks were considered a contributing factor in crash causation. This approach leads to an underreporting of roadwork crashes, a potential underestimation of the problem, and little scope to examine complex interactions of multiple variables and confounding factors in crash data. In such situations it is therefore appropriate to seek alternative and supplementary data as a means to better understand the challenges in improving roadwork safety. With that objective, this paper summarises a qualitative study in which workers were interviewed about their experiences and perceptions of roadwork risks, hazards, incidents and related safety measures. Readers may refer to full length papers published previously on this study for greater detail (Debnath, Blackman, & Haworth, 2013, 2015).

Method

Semi-structured interviews were conducted with 66 roadwork personnel, aiming to identify and explore common roadwork hazards, safety-critical incidents and mitigating measures (see

Appendix for interview schedule). Participants of varying age and experience were recruited from several Queensland sites with assistance from government and industry partners. A variety of roles and occupations were represented, including traffic controllers (25), managers, engineers and supervisors (21), machinery operators and labourers (15), and directors, planners and designers (5). Participants were mostly male (92%) and aged between 30 and 54 years (73%). The interviews were digitally recorded for later transcription, then thematically analysed and coded using Nvivo software. Detailed methodology is reported in Debnath et al. (2015).

Results

Common incidents at roadworks

The most commonly reported incidents involved public vehicle entering work areas. Such incidents were reported by 38% of respondents. Most of these incidents involved the public vehicle hitting a work vehicle, machinery, or worker (excluding traffic controller). Examples of this type of incident include vehicles missing a detour, failing to slow or stop at traffic controls, and driving into closed lanes. The second most commonly reported incident type (33% of respondents) was a public vehicle hitting a traffic controller. The third most commonly reported type of incident was rear end crashes (29% of respondents), most of which were reported to occur at the roadwork zone approaches. Typically, a lead vehicle had stopped or decelerated in response to traffic controls and a following vehicle failed to notice the traffic controller's signals, subsequently colliding with the vehicle in front.

While the three most commonly reported incident types involved public vehicles, the fourth most common type reported involved vehicles and machinery used by roadworkers. Incidents involving a reversing vehicle, mostly a work vehicle or machinery, were reported by 23% of respondents. In particular, roadworkers reported that they get used to hearing reversing beepers all the time, and therefore sometimes become desensitised to the alarms.

Common causes of incidents

The most commonly reported causes of incidents were interrelated and were therefore difficult to quantify in isolation in the current study (see the following section for a breakdown of hazards). Frequently interrelated factors included excessive speed, drivers ignoring traffic controls, and distracted driving. Driver inattention, including not noticing road signs, is likely an important factor in noncompliance with reduced speed limits at roadworks. However, while distracted driving may result in failing to notice traffic controls, it was noted that some motorists deliberately disregard signals and other controls despite having seen them. This is arguably most critical in regard to roadwork speed limits, the perceived credibility of which has been questioned, as reported elsewhere (Blackman, Debnath & Haworth, 2014a, b). Human errors including driver inattention and excessive speed have also been consistently identified as the major causes of roadwork zone crashes in the research literature (Debnath, Blackman, & Haworth, 2012), suggesting that the perceptions of roadworkers are largely accurate on this issue.

As noted above, the workers interviewed did not hold public motorists exclusively responsible for incidents at roadworks. Desensitisation to alarms, worker fatigue, worker arrogance and inattention, poor worksite organisation and unpredictable movement of machinery and work vehicles were also noted as potential or actual contributors to injurious incidents.

Common roadwork hazards

Hazards causing the most concern for respondents were related to driver behaviour. Reflecting the incident types and posited causes, about 60% of respondents reported that most drivers exceed roadwork speed limits in the absence of enforcement and that this was a primary hazard. Distracted driving, particularly mobile phone use, was reported as a common hazard by some (17%) and perceived as a major cause of roadwork crashes. Distracted driving was said to result in motorists disobeying or not noticing signage and traffic lights, which was a major concern to roadworkers. Some 27% of respondents also noted driver frustration and aggression, due at least in part to lengthy and frequent delays as a related hazard which influences drivers' speeding behaviour at roadworks. As well as influencing speed choice, driver frustration and aggression also resulted in verbal abuse, throwing objects, spitting, or threatening traffic controllers.

In terms of environmental conditions, working in wet weather was reported as a hazard by about 30% of the respondents, specifically due to slippery surfaces, reduced skid resistance, greater stopping distances and reduced visibility compared to dry conditions. Related to this, working close to a traffic stream was considered to be a hazard by many respondents (21%). Roadworks during night, dawn and dusk hours were also considered relatively dangerous by 21% of participants, while peak hour works were perceived to be more dangerous than those during off-peak hours. Working on hills and curved roads was perceived as unsafe by some (9% of respondents), mainly because of limited visibility and physical confinement. Often hilly roads and bridges have limited escape paths due to roadside embankments and/or barriers. About 11% of roadworkers found working on highways less safe than on urban or local roads, which was primarily speed-related. Large vehicles are very common on highways where often the reduced speed limit is 80 km/h, compared with 40 km/h on most urban roads. In addition, some traffic controllers (9%) reported that setting up signage was less safe on highways than on urban roads.

Measures to improve roadwork safety

Many participants suggested that currently available safety measures would be adequate if drivers complied with traffic controls and regulations. Clearly this condition is a substantial caveat to the notion of adequacy regarding safety measures, given the widespread documentation of poor compliance with roadwork speed limits. Nonetheless it suggests a perception among participants that measures to improve compliance will bring greater safety improvements than the introduction of new safety measures. Improving compliance with speed limits and other traffic controls can thus be seen as the top priority according to many roadworkers – views which are well supported by research evidence (Debnath et al., 2012). Participants in the study (52%) believed that police presence and enforcement was the most effective measure, reflecting the findings of other research (Arnold Jr, 2003; FHWA, 1998, Debnath et al., 2012). Respondents in the current study also felt that police presence and enforcement has little or no lasting effect once removed, which is also consistent with findings from other studies (Benekohal, Wang, Chitturi, Hajbabaie, & Medina, 2009).

Education and awareness campaigns were highly regarded by 33% of participants in the current study. Some participants claimed that there is not enough educational material for learner drivers regarding work zones, although this may not actually be the case. The Queensland road rules booklet (TMR, 2011) describes roadwork-related signage in the 'Hazardous localities' section. An informative brochure was also produced in 2008 to assist drivers' safe passage through roadwork zones (Queensland Government, 2008) and was generally thought to have been positively received by its target audience (TMR, 2009) (although its impact may have diminished by the time of the current study). While there are some indications that education and awareness campaigns are at least potentially effective, a lack of formal evaluations makes it difficult to compare perceptions with research evidence (Debnath et al., 2012). However, given that one third of study participants were highly supportive of such measures, their direct involvement in designing and delivering educational material in potential future campaigns is worth considering.

Limited effects of static signage on improving safety and their credibility were highlighted by the participants of the current study. Participants recognised that the practice of leaving roadwork signs out when no roadworkers are present contributes to greater complacency and frustration among drivers. This has been noted in related studies within the current project (Blackman et al., 2014a, b). However, the consequences of leaving signage out while no work is being undertaken must be balanced against the risks involved in retrieving and later repositioning signage. A more detailed breakdown and discussion of the perceived effectiveness of safety measures is provided in Debnath et al. (2015).

Limitations

There are inherent limitations in this study as in virtually all studies that rely on self-report data. The perceptions and beliefs reported by participants may not have been entirely accurate in all cases and may have been somewhat biased in relation to their specific roles. However, given the general nature of the questions and the assurance that their individual responses would remain confidential, there was arguably little motivation for participants to give deliberately misleading statements.

Conclusions

This study fills a key gap in the literature on understanding the perceptions of road construction and maintenance staff regarding roadwork incidents, their causes, hazards, and mitigating measures. Results from semi-structured interviews with 66 roadwork personnel revealed that perceived hazards at roadwork sites arise from a range of driver, environmental, worker and equipment factors. Driver factors include speeding, distraction, confusion and lack of awareness, frustration and aggression, impairment, fatigue and general non-compliance with traffic controls. Environmental factors include rain and poor weather conditions, poor lighting, obscured vision, limited working space and noise (ineffective alarms, machinery noise). Worker and equipment factors were less prevalent in the overall findings, but included inattention, communication problems, machinery proximity and unpredictability, and worker ignorance and arrogance. Roadworkers perceived that improving credibility of roadwork signage and driver compliance with posted speed limits could mitigate many of the common roadwork hazards. Driver education and public awareness campaigns were also perceived as highly effective measures to improve roadwork safety.

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Appendix

QUESTIONS FOR SEMI-STRUCTURED INTERVIEWS (treat most as open-ended)

Work role information:

- For how many years have you been working on roadworks sites?
- For how long have you worked at this site? - *(full-time or part-time)*
- What is your main role at work? *- (e.g., Traffic control, machinery/vehicle operator, site supervision, site management, design)*
    - Do you have any other roles – if so, what are they?

- In which parts of the site do you do most of your work? *– (e.g., office, off-road areas, behind barriers, in traffic lane)*
- At what times do you do most of your work *(day/night, weekday/weekend)?*
- Do you move around the site on foot much during your shift, or do you generally stay within a small area or stay inside your work vehicle?

Characteristics of past incidents:

- Have you experienced, seen or heard of any serious incidents at roadwork sites? Can you describe what happened?
    - What do you think could be done to prevent this happening again?

Perceived effectiveness of safety practices:

- What safety practices are used at this site and how effective are they?

- What changes would improve the safety of your worksite?
    - Are there any effective measures you're aware of that are not used where you work?

Perceived hazards:

- In which situations at roadworks do you feel unsafe? *– (e.g., work time, weather condition, working far from other workers, exposed to traffic, others)*
    - What are the particular hazards or dangers in those situations?

- What do you feel is a safe distance? *- (Less than 3 metres, 3 to 5 metres, more than 5 metres)*
    - Do you think that vehicles travel too close past where you are working? *- (Never, rarely, sometimes, most of the times, always)*

- What do you feel is a safe speed? *- (Less than 20Km/h, 20-40km/h, 40-60km/h, 60-80km/h, above 80Km/h)*
    - Do you think that vehicles travel too fast past where you are working? *- (Never, rarely, sometimes, most of the times, always)*

- Are there any particular types of vehicle you consider more dangerous to you than others? *- (Car, Truck, Motorcycle)*
    - If so, why do you think these vehicles are dangerous? *- (e.g., Travels too close, travels too fast, frequently disobey traffic rules, any other reason)*

Demographic details:

- Age *- (<30, 30-54, 55>)*
- Gender

Speeding Through Roadworks: Understanding Driver Speed Profiles and Ways to Reduce Speeding

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Abstract

Poor compliance with speed limits is a serious safety concern at roadworks. While considerable research has been undertaken worldwide to understand drivers' speeding behaviour at roadworks and to identify treatments for improving compliance with speed limits, little is known about the speeding behaviour of drivers at Australian roadworks and how their compliance rates with speed limits could be improved. This paper presents findings from two Queensland studies targeted at 1) examining drivers' speed profiles at three long-term roadwork sites, and 2) understanding the effectiveness of speed control treatments at roadworks. The first study analysed driver speeds at various locations in the sites using a Tobit regression model. Results show that the probability of speeding was higher for light vehicles and their followers, for leaders of platoons with larger front gaps, during late afternoon and early morning, when higher proportions of surrounding vehicles were speeding, and at the upstream of work areas. The second study provided a comprehensive understanding of the effectiveness of various speed control treatments used at roadworks by undertaking a critical review of the literature. Results showed that enforcement has the greatest effects on reducing speeds among all treatments, while the roadwork signage and information-related treatments have small to moderate effects on speed reduction. Findings from the studies have potential for designing programs to effectively improve speed limit compliance at Australian roadworks.

Introduction

Poor compliance with speed limits is a serious safety concern at roadworks (Allpress & Leland Jr, 2010; Brewer, Pesti, & Schneider, 2006; Debnath, Blackman, & Haworth, 2015). Despite numerous studies on understanding speeding behaviour at roadworks (Allpress & Leland Jr, 2010; Brewer, et al., 2006; Daniel, Dixon, & Jared, 2000; Hajbabaie, Ramezani, & Benekohal, 2011; Haworth, Symmons, & Mulvihill, 2002), little is known about the speeding behaviour of drivers at Australian roadworks and how their compliance rates with speed limits could be improved. This paper presents findings from two Queensland studies targeted at 1) examining drivers' speed profiles at roadwork sites, and 2) understanding the effectiveness of speed control treatments at roadworks.

Method

The first study measured driver speeds at four points within three long-term work zones (referred to hereafter as Sites 1 - 3) in Queensland. Schematic diagrams of the work zones showing the posted speed limits and the location of the four speed measurement points are presented in Appendix A. Site 1 was an undivided sealed two lane road (one lane each way) with pre-work speed limits of 100 km/h (southern end) and 80 km/h (northern end). Work (resurfacing) involved full closure of one lane within the activity area, with the open lane alternating (southbound/northbound) as required. At Site 2, work involved the addition of an extra lane in each direction to the existing two lanes (one each way). The pre-work speed limits were 90 km/h at the southern end of the work zone and 80 km/h at the northern end.

Site 3 comprised two lanes in each direction, divided by a 15 meter wide median, with 100 km/h pre-work speed limit. Work involved construction of a new westbound slip lane exiting a fuel station, with no traffic interruptions in the eastbound lanes. Speed data were collected from all sites using pneumatic tubes over a continuous period of seven days.

The speed data was analysed descriptively to obtain the mean speeds and the proportions of vehicles speeding at each speed measurement point in the sites. In addition, a Tobit model (see Debnath, Blackman, & Haworth, 2014 for a detailed description of the model) was applied to examine how different characteristics of vehicles and their surrounding traffic affect driver speeds. The model estimated the probability of speeding and the extent of speeding (i.e., the difference between the observed speed and the posted speed limit) for different vehicular and traffic characteristics.

The second study involved a review of the literature to understand the effectiveness of various speed control treatments. The treatments were categorised into four groups: Informational, Physical, Enforcement, and Educational treatments.

Results

Driver speed profiles in roadwork zones

The descriptive statistics of the speed profiles and magnitude of compliance with posted limits for the three work zones (Sites 1-3) are presented in Appendix B. The average speeds at Point 1 (after the first speed reduction sign) were higher than the posted speed limits in all sites. In addition, the percentages of vehicles speeding were higher at Point 1 than at other points, indicating that motorists generally speed more in the upstream work zone areas.

Before the activity area at Site 3, there were two speed limit reductions: first to 80 km/h from 100 km/h at Point 1, and then to 60 km/h (day hours) or to 70 km/h (night hours) at Point 2. The almost equal average speeds under the different speed limits and their corresponding rates of speeding (83% at point 1 and 97% at point 2) suggest that the speed reduction signage in upstream work zone areas may have very limited effects on travel speeds.

At the start of the activity area (Point 3), the average speeds were higher than the posted speed limits at Sites 2 and 3, with 89% and 72% of vehicles speeding, respectively. At the end of the activity areas (Point 4), the average speed was higher than the posted speed limit at Site 3, but was lower at Site 1 and about equal at Site 2 (still about half of the vehicles violated the posted speed limit, but mostly by small margins). The night-time speeds were significantly higher than the daytime speeds at Site 1 (4.4 km/h) and Site 2 (5.4 km/h).

The average speed measured at a location downstream of a stop/slow traffic controller (Point 2) at Site 1 was lower than the posted limit of 60 km/h with higher mean speed during night hours than during daytime. These findings might imply that motorists drive at lower speeds when passing a traffic controller standing on road, particularly during the day hours.

The estimates of the Tobit model (Appendix C) showed that relative to the 3-6pm hours, a lower percentage of vehicles were speeding during the other daytime hours (6am-3pm) at both Site 1 and Site 2. A driver had 7.3% and 3.5% higher probability of being non-compliant at Site 3 and Site 1 work zones respectively during the early morning hours (10am-3am).

The probability that a driver will be non-compliant was highest at Point 1 (after first speed reduction sign), for Site 1 (12.5%) and Site 2 (13.2%), with corresponding increases of 0.95 and 2.50 km/h in the excess speeds (i.e., amount of speed over the posted limit). At the beginning of the activity areas (Point 3), the probabilities of exceeding speed limits were 2.6% (Site 1), 11.2% (Site 2), and 1.1% (Site 3) higher than those at the end of activity area. The findings suggest that relative to the end of the activity area (Point 4), the magnitudes of speeding at the other locations (i.e., start and upstream of activity area) were likely to be significantly higher.

Compared to light vehicles, all work zones observed lower magnitudes and probabilities of non-compliance for medium vehicles. Similar results were found for the effects of types of lead vehicles on the following vehicle's speeds. Relative to the vehicles with a small gap to the vehicles in front (<= 2 seconds), vehicles with larger gaps were more likely to travel at higher speeds and to exceed the posted speed limits. Relative to the leaders of platoons, the follower vehicles had lower magnitudes and probabilities of non-compliance. The vehicles in a platoon with 2nd to 5th rank (considering the leader of the platoon as ranked 1st) and those in the tails of platoons (ranks 6th and beyond) had lower probabilities of being non-compliant. On the other hand, vehicles not in a platoon had higher probabilities of being non-compliant than the leaders of platoons. These results demonstrate that the speed of a particular vehicle and the probability of it exceeding the posted limits not only depend on its type but also on the type of vehicle it is following.

An increase in the proportion of vehicles in surrounding traffic that were exceeding posted speed limits was associated with the increase in speeds and probabilities of exceeding speed limits of other vehicles. Similar results were obtained for an increase in the proportion of vehicles which exceeded the posted limits by a large margin (at least by 20 km/h). These results indicate that a driver's speed at a particular point is significantly influenced by the speed profiles of other drivers travelling through the same point in a short time interval.

Effectiveness of speed control measures

Informational treatments

Regulatory speed limit signs were found to reduce speeds in general, but they do not bring the speed down to the posted limits (Haworth, et al., 2002). In a Victorian survey (VicRoads, 1990), only 43% of drivers reported adjusting their speeds according to speed limits. About 14% and 30% chose their speeds based on their perception of suitable speed and road conditions, respectively, without regard to the posted limits. The remaining 13% reported that they failed to notice the speed limit signs or felt that the signage was inadequate. The advance warning signs, on the other hand, seemed to have less effect on speeds than regulatory speed limit signs (Huebschman, Garcia, Bullock, & Abraham, 2003; VicRoads, 1990).

Variable message signs (VMS) produce larger speed reductions than the traditional static signage. Brewer, et al. (2006) and Bai, Finger, and Li (2010) showed VMS to be more effective than the traditional signage in reducing the number of speeding vehicles. Fontaine, Carlson, and Hawkins Jr. (2000) found VMS in combination with speed feedback systems reduced speeds by up to 16 km/h, whereas VMS alone resulted in about a 3 km/h speed reduction. Some researchers argued that the effects of VMS and speed feedback systems are temporary. Meyer (2004) found that radar-activated VMS had only a "novelty effect" which was not sustained over time but other research (Wang, Dixon, & Jared, 2003) found effects three weeks after installation. Innovative and attention-grabbing messages were tested by

Wang, et al. (2003) and found immediate speed reductions of 0.3-2.9 km/h in daylight conditions in one worksite, but another site showed little effect. Huebschman, et al., (2003) displayed the number of traffic fines issued to date, but found this ineffective.

Physical treatments

Inconsistent findings were obtained on the effectiveness of rumble strips in reducing speeds. Meyer (2000) reported speed reductions for both cars and trucks. Fontaine and Carlson (2001) observed 2 mph smaller speed reductions for cars in comparison with trucks. However, Horowitz and Notbohm (2005) reported that speed reductions due to rumble strips were not constantly present in a Missouri study. Considering the factors related to deployment of rumble strips (e.g., time to lay the strips, workers exposed to traffic), rumble strips might not be suitable for transient and moving sites. Optical speed bars were found to have relatively small but statistically significant reductions in speeds (Meyer, 2004).

Enforcement and educational treatments

Enforcement measures were the most effective means to reduce speeds but these measures often demand allocation of significant resources (Ross & Pietz, 2011). The presence of a speed camera (Benekohal, Hajbabaie, Medina, Wang, & Chitturi, 2010; Huebschman, et al., 2003; Joerger, 2010) or a police car with flashing lights showed significant effects on improving speed limit compliance, but the downstream effects were limited (Benekohal, et al., 2010). Imposing higher fines for violating speed limits showed little effect on speed reduction (Ross & Pietz, 2011; Ullman, Carlson, & Trout, 2000). Haworth, et al. (2002) argued that considerations need to be taken on increasing the likelihood of speeding drivers being detected, instead of only increasing the amount of fines.

Educational measures have the potential to improve public awareness of the risks involved at roadworks, but reliable evaluations are lacking regarding their effectiveness in terms of objective measures of speed reductions (Haworth, et al., 2002; Ross & Pietz, 2011). However, it is noteworthy that deployment of safety measures at roadworks without proper public awareness of the associated risks is unlikely to be effective.

Conclusions

This paper presents findings from two Queensland studies to examine the speed profiles of drivers at various locations in roadwork zones and to understand the effectiveness of speed control measures used at roadworks. Results from the analysis of driver speed profiles showed that the probability of speeding was higher for light vehicles and their followers, for leaders of platoons with larger front gaps, during late afternoon and early morning, when higher proportions of surrounding vehicles were speeding, and at the upstream of work areas. A review of the literature on the effectiveness of speed control measures showed that enforcement has the greatest effects on reducing speeds among all treatments, while the roadwork signage and information-related treatments have small to moderate effects on speed reduction.

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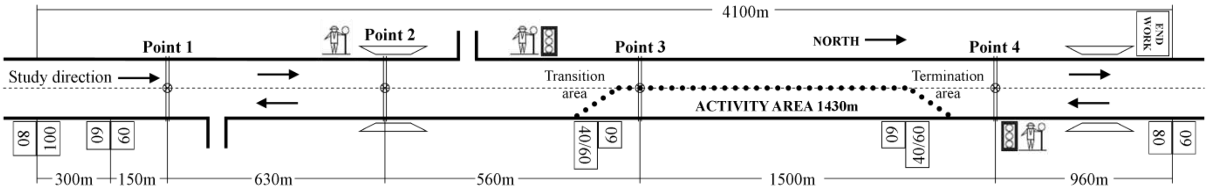
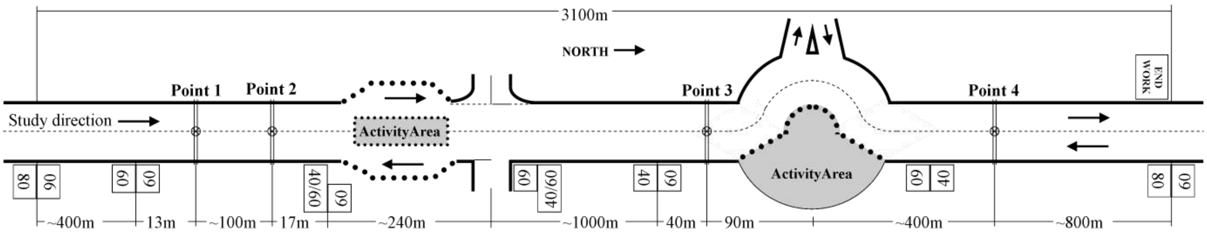
Appendices

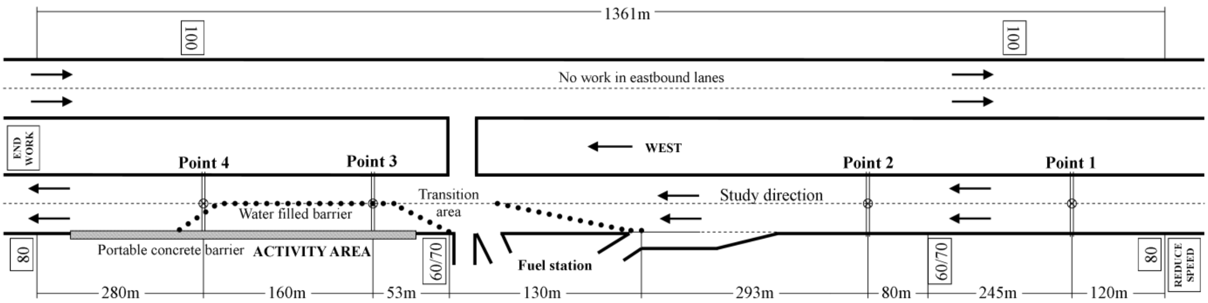
Appendix A Schematic diagrams of roadwork zones



Site 1 work zone plan



Site 2 work zone plan



Site 3 work zone plan

Appendix B Descriptive statistics of speed profiles and speed limit compliance

Work zone	Point	No of obs.	Posted speed limit	Mean Speed (km/h)	S.D.	% vehicles speeding	% speeding by at least 5 km/h	% speeding by at least 20 km/h	Mean speed difference (Night-Day)[a]	Mean speed difference (99% CI)
Site 1	1	23906	60	68.4	14.2	76.6	61.6	18.9	**8.5**	(8.0, 9.0)
Site 1	2	22141	60	50.1	11.7	19.4	11.4	1.7	**13.3**	(12.9, 13.7)
Site 1	*3	11725	40	43.5	8.2	66.4	44.2	1.7	**-3.6**	(-4.8, -2.5)
Site 1	*3	6302	60	44.7	10.9	8.8	2.9	0.1	**-8.5**	(-9.2, -7.9)
Site 1	4	19082	60	49.2	7.7	6.8	1.8	0.1	**4.4**	(4.1, 4.7)
Site 2	1	53085	60	74.7	8.6	95.5	88.2	25.4	**5.6**	(5.3, 5.8)
Site 2	3	58858	40	49.1	7.6	89.2	73.5	6.1	**4.7**	(4.5, 4.9)
Site 2	4	57881	60	59.4	7.4	48.4	18.5	0.5	**5.4**	(5.1, 5.6)
Site 3	1	79149	80	89.4	10.3	83.2	67.4	14.5	**0.5**	(0.3, 0.7)
Site 3	*2	48612	60	86.3	13.0	97.6	95.3	72.5	-	-
Site 3	*2	14796	70	89.0	11.2	96.9	90.4	44.7	**-1.1**	(-1.9, -0.3)
Site 3	*3	62199	60	67.7	14.2	72.7	59.8	18.6	-	-
Site 3	*3	18108	70	76.3	14.2	71.9	55.8	15.4	0.6	(-0.4, 1.6)
Site 3	*4	58532	60	70.9	12.2	84.4	70.9	21.2	-	-
Site 3	*4	17054	70	79.2	11.2	79.6	62.4	16.9	0.4	(-0.4, 1.2)

* Points with different speed limits during day and night periods, - No observation during night-time, **Bold values:** significant at 99% confidence level, [a] H_0: diff (mean night - mean day) = 0 with H_a: diff>0 (if diff is positive) or H_a: diff<0 (if diff is negative)

Appendix C Tobit model estimation results

Explanatory variables	Site 1		Site 2		Site 3	
	Expected value sensitivity[c]	Zero sensitivity (%)[d]	Expected value sensitivity[c]	Zero sensitivit y (%)[d]	Expected value sensitivity[c]	Zero sensitivit y (%)[d]
Time of day						
00:01 - 03:00	0.27	3.52	0.39	1.65	0.29	7.32
03:01 - 06:00	0.12	1.65	-0.06	-0.28	0.03	0.08
06:01 - 09:00	-0.15	-1.95	-0.32	-1.56	0.08	0.20
09:01 - 12:00	-0.15	-1.94	-0.35	-1.68	-0.09	-0.24
12:01 - 15:00	-0.10	-1.33	-0.09	-0.44	-0.06	-0.17
15:01 - 18:00	a		a		a	
18:01 - 21:00	-0.05	-0.70	-0.38	-1.85	-0.07	-0.19
21:01 - 24:00	0.02	0.27	-0.28	-1.36	0.00	0.01
Speed measurement point						
1	0.95	12.53	2.50	13.23	0.07	0.20
2	0.52	6.99	NA		0.30	0.81
3	0.19	2.57	1.92	11.18	0.43	1.13
4	a		a		a	
Posted speed limit	-2.09	-25.69	b		b	
Type of vehicle						
Light vehicle	a		a		a	
Medium vehicle	-0.63	-8.42	-0.54	-2.81	-0.38	-1.03
Heavy vehicle	-0.82	-10.94	-1.26	-7.45	-0.57	-1.58
Gap (from front vehicle)						
<=2 seconds	a		a		a	
2.1 - 4 seconds	0.13	1.74	1.27	6.34	1.66	4.50
4.1 - 8 seconds	0.35	4.63	1.26	6.30	1.15	3.30
8.1 - 14 seconds	0.94	12.44	1.58	7.52	0.98	2.86
>14 seconds	1.07	14.04	0.70	3.85	1.16	3.30
Type of vehicle in front						
Light vehicle	a		a		a	
Medium vehicle	-0.29	-3.88	-0.35	-1.75	-0.20	-0.55
Heavy vehicle	-0.25	-3.27	-1.10	-6.38	-0.24	-0.64
Order of vehicle in platoon						
No platoon	0.61	8.01	1.33	5.22	0.82	2.10
Platoon leader	a		a		a	
2nd-5th in platoon	-0.30	-4.03	-0.60	-3.27	-0.41	-1.22
6th and beyond	-0.65	-8.69	-2.17	-15.98	-2.20	-8.03
Traffic volume	0.01	0.07	0.00	0.01	0.01	0.02
Proportion of medium vehicles	-		-0.01	-0.04	-	
Proportion of heavy vehicles	-		-		-	
Proportion of vehicles speeding	0.07	0.88	0.10	0.50	0.16	0.43
Proportion of vehicles speeding by 20 km/h	0.05	0.61	0.12	0.59	0.16	0.44
Lane	NA		NA		0.16	0.42

[a] Reference category, [b] Removed due to correlation, NA Not Applicable, - Not significant at 95% confidence level, [c] Change in the expected value of excess speed (observed speed – posted speed limit), [d] Change in the probability of exceeding posted speed limits.

Evaluation of Safety Treatments at Roadwork Zones

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Abstract

A major 3-year research project to improve safety at roadworks has recently been completed by the Centre for Accident Research and Road Safety – Queensland (CARRS-Q) and industry partners. This project involved developing strategies to mitigate roadwork hazards including speeding. This paper presents three on-road evaluation studies on the effectiveness of some current and new safety treatments: use of pilot vehicles, variable message signage (VMS), police enforcement with and without VMS, and remote-controlled traffic control devices. The speed reduction potential of pilot vehicles was evaluated at a highway site. Results showed that pilot vehicles reduced average speeds within the work area, but not at a downstream location. Combinations of VMS and police enforcement were evaluated at a motorway site and results showed that police enforcement accompanied with VMS had greater effects on reducing speeds than either of these treatments alone. Three new remote-controlled traffic control devices—red and amber lights, red light and amber arrow, and a robotic stop/slow sign—were evaluated at a highway site. Results showed that the red light and amber arrow option produced consistent effects on the speeds at the approach to traffic controls and at a location inside the work area. This paper presents the first rigorous evaluations of these roadwork safety treatments in Queensland.

Introduction

Excessive speeds at roadwork zones pose significant risks to roadworkers and motorists (Allpress & Leland Jr, 2010; Debnath, Blackman, & Haworth, 2015; Garber & Zhao, 2002). A recent study of driver speeds in three Queensland roadwork zones (Debnath, Blackman, & Haworth, 2014) reported that drivers violate the posted speed limits at all stages of roadworks (advance warning area, taper area, work area, and termination area), often with high margins over the posted limits. For example, almost all drivers (77-98%) drove over posted speed limits when approaching a roadwork zone, while many (19-45%) drove at 20 Km/h or more over the posted limits. The high rate of speeding is known to be associated with roadwork crashes. Speeding was cited as a contributing factor in 42% of work zone crashes in Texas (Brewer, Pesti, & Schneider, 2006), 7% of fatal crashes in Georgia (Daniel, Dixon, & Jared, 2000), and 25% and 16% of fatal and injury crashes respectively in Kansas (Bai & Li, 2011).

The dangers caused by excessive speeds in roadwork zones motivated this study to evaluate potential safety treatments for reducing driver speeds at roadworks. This research was a part of a recently completed major research project on improving the safety at roadworks hosted at the Centre for Accident Research and Road Safety – Queensland (CARRS-Q). The findings obtained from three studies evaluating the effectiveness of speed control treatments at roadwork zones are presented in this paper.

Method

To three on-road evaluation studies involved evaluating the speed reduction potentials of pilot vehicles, variable message signage (VMS), police enforcement with and without VMS, and remote-controlled traffic control devices. The evaluation methodologies for each study are discussed in the subsequent paragraphs.

Effectiveness of pilot vehicles was evaluated in a long-term rural two-lane highway roadwork zone (Bruce Highway) where one lane was closed for roadworks and the other lane was alternating two-way traffic, controlled by manual stop/slow method. A pilot vehicle was used to guide the traffic on the open lane on three days in a five day study period (i.e., there was no pilot vehicle on the other two days). Driver speeds were measured at two locations: (1) within the work area where the pilot vehicle was operating and (2) at a location after the work area (not covered by the pilot vehicle) to examine downstream effects. A detailed description of the data collection plan and the data analysis method is available in Debnath et al. (2014).

Effects of VMS with and without (overt) police enforcement were studied in a long-term motorway work zone (Pacific Motorway, near Gold Coast). A VMS was placed ahead of the work area which displayed messages ‘Roadwork speed limits are enforced’, ‘Speed cameras operate in roadworks’, ‘Slow down for road worker safety’, and ‘Slow down, road workers on site’. Police enforced the 60 km/h posted speed limit using a speed camera on three days (5 hours each day). Among these three enforcement days, the VMS was active on two days. This study design produced three combinations of police enforcement and VMS: (1) only VMS was active, (2) police enforcement without VMS, and (3) police enforcement with VMS. These combinations allowed examining both the individual and combined effects of VMS and police enforcement on driver speeds. Reductions in mean speeds and proportions of vehicles speeding at various margins (5 km/h, and 20 km/h over the limit) were computed.

Three new remote-controlled traffic control devices—amber and red lights (A-R), amber arrow and red light (AA-R), and a robotic stop/slow sign (RS)—were evaluated at a rural highway roadwork zone (Moonie Highway, southern QLD). Out of the two lanes of the highway, one was closed for roadworks. The other lane served alternating traffic from both directions using manual stop/slow methods. The new traffic control devices were remotely controlled and therefore it was possible to reduce the exposure of human traffic controllers (HTC) to traffic by allowing them to be positioned away from road. Traditional traffic control devices including HTC and Green-Amber-Red traffic lights (G-A-R) were also used to provide baseline reference for evaluating the effectiveness of the new TC options. Effectiveness was assessed using three measures: compliance with stop condition, speeds ahead and after the traffic controls, and driver understanding of the traffic control devices. Speeds were measured using pneumatic tubes at three points: (1) 50m after the first speed reduction sign, (2) 30m ahead of traffic controls, and (3) 70m after traffic controls. A roadside survey was conducted at the other end of the site among the drivers who stopped at the front of the traffic queue. Drivers were asked questions regarding their understanding of the different traffic control devices and their preferences, if any.

Results

Evaluation of pilot vehicle operation

The mean speed of all vehicles under a posted speed limit of 40 km/h was 5.9 km/h lower (dropped from 52.0 to 46.1 km/h) when a pilot vehicle was in operation. The size of the reduction did not differ significantly by type of vehicle. Despite these reductions, the mean speed of all vehicles remained 6.1 km/h above the posted limit under pilot vehicle operation.

Under pilot vehicle operation, the proportion of speeding vehicles fell by 12.5%. Almost all vehicles (97.8%) violated the posted limit in the absence of the pilot vehicle, whereas 85.3% did so when it was present. The largest reduction in prevalence of speeding was seen for medium vehicles (15.0%), followed by heavy (12.8%) and light vehicles (12.1%). The effect of the pilot vehicle in reducing speeding vehicles was greater (32.7%) in the case of travelling at least 5 km/h above the posted limit. Similar patterns of reductions were seen for the three types of vehicles. Despite these reductions, 55.7% vehicles (again with a smaller share of medium vehicles than the other types of vehicles) still travelled at least 5 km/h above the limit. The greatest reduction occurred in the proportion of vehicles travelling at least 10 km/h over the limit (38.1%) with a greater reduction for medium vehicles (40.4%) than the light (37.9%) and heavy vehicles (37.8%). Results indicated that the pilot vehicle has greater effects in reducing speeds of the vehicles following it closely in a traffic stream (i.e., smaller gaps between vehicles) than those which are far behind the traffic stream and have larger gaps from their preceding vehicles.

While the pilot vehicle reduced driver speeds considerably, the pilot vehicle itself was found exceeding the posted limit on 34% of its trips, and exceeded the limit by 5 km/h or more on 7.4% of the trips. No significant effects of the pilot vehicle on the downstream speeds were observed.

Evaluation of VMS and police enforcement

Both the separate and combined use of police enforcement and VMS resulted in reductions in the mean speeds. Police enforcement alone led to a 1.1 km/h mean speed reduction, whereas VMS alone showed a 2.8 km/h reduction. However, a greater reduction was found (4.2 km/h) when police enforcement was accompanied by VMS.

A similar trend was observed for the reductions in the proportions of speeding vehicles achieved by the three treatment options. About 27% fewer vehicles violated the posted speed limit when both VMS and police enforcement were present. On the other hand, police enforcement and VMS separately showed reduction of 4% and 20% respectively. About 27% reduction was observed in the percent of vehicles travelling at least 5 km/h over the speed limit when both VMS and police enforcement were present. About 4% and 14% reductions were observed for police only and VMS only conditions, respectively. In the case of speeding by a larger margin (10 km/h over the limit), the trend remained similar to the above findings. About 15% reduction was observed in the percent of vehicles travelling at least 10 km/h over the speed limit when both treatments were present. Police enforcement alone produced a 3% reduction, whereas VMS alone produced 7% reduction. The reductions in the percent of vehicles speeding by at least 20 km/h were not meaningful as only about 0.5-2.5% vehicles were speeding by 20 km/h when no treatments were present.

Overall, it appears that while both VMS and police enforcement effectively reduce driver speeds and rates of speeding at different margins over the speed limit, the greatest effects were obtained when both treatments were present together. A possible explanation for this finding is that drivers might become more aware of the risk of getting a fine for speeding by reading the VMS messages and then seeing a police car parked on the side of the road.

Evaluation of remote-controlled traffic control devices

Results showed 100% compliance rates with the direction to stop for all traffic control devices, except for the RS which had 4 vehicles fail to stop in 6.7 hour observation period.

The mean speeds ahead of the traffic control location were higher for all traffic control devices (G-A-R: 4.8 Km/h, A-R: 7.3 Km/h, AA-R: 5.0 Km/h, and RS: 6.0 Km/h) than the HTC. The highest speeds were found for A-R. Under this condition drivers may have increased their speed anticipating an imminent change from solid Amber to Red. This does not seem to have occurred under AA-R where mean speed was similar to G-A-R.

At a location inside the work area, mean speeds were similar for HTC, G-A-R and AA-R (less than 1 km/h difference). Speeds for A-R and RS were lower than for HTC (4.4 and 2.6 Km/h, respectively). The relatively low speed for A-R likely reflects a greater speed reduction after approaching (and passing) the TC location at relatively high speed.

While most drivers understood ‘when to stop’ and ‘when to go’ for G-A-R and RS devices, the A-R and AA-R devices caused some confusion. While about 93% and 94% drivers understood when to stop for the A-R and AA-R devices respectively, the corresponding values for when to go were rather low (33% and 24% respectively). Asked what they would do upon seeing an amber (A-R) light, 10 of 69 drivers were unsure of its meaning (‘caution’/‘go’), while another 9 said they would call the fault line to report a fault. Similarly, 16 of 69 drivers were unsure what to do upon seeing an amber arrow (AA-R).

Drivers’ preferred option for knowing ‘when to stop’ was the G-A-R condition (66.9%), followed by RS (27.7%), A-R (3.6%) and AA-R (1.5%), while 6.9% had no preference (includes multiple responses). The best option for knowing ‘when to go’ was clearly G-A-R (82.9%), followed by RS (23.3%), AA-R (4.7%) and A-R (3.1%). These values suggest that drivers like to see on road what they are familiar with. The driver survey indicates that driver education campaigns may be necessary before widespread implementation of the new traffic control devices.

Conclusions

Findings from three on-road evaluation studies of roadwork safety treatments showed promising results. A pilot vehicle effectively reduced driver speeds and proportions of speeding vehicles within the work area, but did not bring the mean speeds down to posted speed limit and did not show significant effects on the speeds at a location downstream of the work area. Police enforcement and VMS were found to reduce driver speeds, but greater reductions were achieved with these treatments used in combination. The new remote controlled traffic control devices showed promising results in reducing driver speeds before and after the traffic control location, but the roadside driver survey revealed that the two-aspect traffic lights (amber light and amber arrows) caused confusions among some drivers. These devices, however, were successful in reducing the exposure of the human traffic controllers by allowing them to stand away from the road.

Acknowledgements

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Contribution of vehicle safety improvements and infrastructure investment on reducing road trauma in Victoria and projected future benefits

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Abstract

Vehicle safety and infrastructure improvements are two major road safety program areas that have made significant contributions to the reduction of road trauma under the Safe System. In Victoria over the past 10 years, there have been increasing improvements in the safety of the vehicle fleet and significant investment in safer road infrastructure through the TAC funded Safer Road Infrastructure Program (SRIP). The aim of this work was to estimate the impact of each road safety program area on road trauma as represented by measured improvements in the light vehicle fleet and major investment in safer infrastructure through SRIP, and to project their future benefits. Time series models were constructed over the period 2006 to 2014 with separate models developed for fatalities and serious injuries. These models were then used to produce forecasts of future trends in deaths and serious injuries. It was evident that each program area has been very successful in achieving significant savings in death and serious injury. However, the estimated fatal and serious injury future trends indicated that the ongoing issue of serious injury trauma will require particular focus and effort by road safety policymakers to address. Whilst this work demonstrates the effectiveness of vehicle safety improvements and infrastructure investment on preventing serious road trauma, the projected future benefits of these key road safety program areas highlight how critically important it is to continue to invest in proven road safety programs if the benefits that have been achieved thus far are to continue going forward.

Introduction

Vehicle safety and infrastructure improvements are two major road safety program areas that have made significant contributions to the reduction of road trauma under the Safe System. In Victoria over the past 10 years, there have been increasing improvements in the safety of the vehicle fleet and significant investment in safer road infrastructure through the TAC funded Safer Road Infrastructure Program (SRIP). Improvements in the overall safety of the vehicle fleet have been demonstrated by Newstead, Watson, and Cameron (2014) who found significant improvements in secondary safety of the Australian vehicle fleet as measured by crashworthiness, or the risk of driver death or serious injury in the event of a crash, with increasing year of manufacture. Early improvements can be attributed to the introduction of major Australian Design Rules (ADRs) for passenger vehicles with standards covering seatbelt fitment, energy-absorbing steering columns, head restraints and improved cabin strength, with more recent vehicle secondary safety improvements including seatbelt pre-tensioners, anti-whiplash seats, active head restraints and frontal, side and knee airbags (Langford, 2009). These improvements have translated into improvements in the average safety of the light vehicle fleet as a whole over time, as demonstrated by Newstead and Scully (2009), as older vehicles are removed from the fleet and safer new vehicles enter the fleet.

Major investment in road infrastructure through the SRIP program was announced by the Victorian government in 2004 with the aim of reducing deaths and serious injuries through infrastructure improvements on arterial roads. Stage 1 (2004-2008) delivered 113 projects focusing on run-off-road and intersection crashes at a cost of $130 million. Run-off-road treatments included shoulder sealing, safety barriers (wire rope barriers and/or guard fences) and tactile lines. Intersection treatments included fully controlled right turns, new traffic signals and roundabouts. Stage 2 (2006-2008) delivered 252 projects at a cost of $110m continuing with run-off-road treatments and expanding the focus on intersection treatments. Stage 3 (from 2007) is delivering projects to the value of $650m over a 10 year period, and also includes treatments at 40 km/h shopping strips, school zones and greyspots such as Y intersections.

The aim of the analysis presented in this paper was to estimate the individual impact of improvements in the light vehicle fleet and major investment in safer infrastructure through SRIP investment on overall road trauma in Victoria and to project their future benefits. Analysis is based on previous research evaluating the effects of each of these countermeasure areas on road trauma. The road trauma impacts of SRIP along with the economic worth of the program have been estimated through a comprehensive evaluation of each phase of the program detailed in Budd, Newstead and Scully (2011) and Budd, Scully and Newstead (2011a, 2011b). The impact of the changing composition of the light vehicle fleet on annual observed road trauma in Australia has been estimated by Budd, Keall and Newstead (2015).

Method

Time series models were constructed over the period 2006 to 2014 with separate models developed for fatalities and serious injuries. These models were then used to produce forecasts of future trends in deaths and serious injuries to 2025. Specifically, the effect of each program area on reducing fatalities and serious injuries at each time period was estimated based on prior research. The observed time series of data was then adjusted to give the expected time series of data had each program not been implemented (called the residual time series). Forecasts were then made on the residual time series to estimate expected future road trauma had vehicle safety improvement and SRIP investment not happened. Estimated future trauma reductions due to vehicle safety improvements and SRIP investment were then derived from the previous research and information on planned future SRIP expenditure to estimate the impact these programs will have on expected future road trauma. These estimates were applied to the forecast residual time series to quantify the trauma savings expected. Data was extracted from the VicRoads Road Crash Information System (RCIS), with fatality data used directly whereas serious injury data was validated against TAC claims data in order to overcome any reporting inaccuracies related to the measurement of serious injury in Victoria (D'Elia & Newstead, 2014). The periodicity on which the data was analysed was determined by the data quantities available in order to get reasonable periodic crash counts for analysis. Monthly data counts were found to be sufficiently large for both fatal and serious injury series for analysis.

The analysis was based on the structural time series models developed by Harvey (1989) which are formulated directly in terms of trend μ_t, seasonal s_t and irregular ε_t (noise) components. These models are like the classical decomposition model defined by:

$$y_t = \mu_t + s_t + \varepsilon_t$$

in which the components are of direct interest themselves. However, unlike the classical decomposition model, in which the trend and seasonal components are deterministic (fixed), structural time series models allow for random (stochastic) variation in these components.

The models were explicitly set up to examine the impact on road trauma of the two major road safety program areas highlighted by this paper, namely improvements in safety of the Victorian light vehicle fleet and investment in road infrastructure improvements through SRIP. The effects of each program area were estimated as follows.

Estimating vehicle crashworthiness effects

The crashworthiness metric used in this analysis estimates the risk of vehicle occupant serious injury or death given involvement in a crash. Effects of vehicle crashworthiness improvement on monthly road trauma were estimated by quantifying the cross-sectional secondary safety of the crashed light vehicle fleet each year and estimating how this has changed over time. Budd, Keall and Newstead (2015) undertook this calculation for the Australian light vehicle fleet over the period 2000 to 2010 inclusive. They noted that during this time, the average cross-sectional crashworthiness of the Australian light vehicle fleet (the average risk of death or serious injury to the vehicle occupant in a crash) improved by 27%, an average of 3% compounding each year. These estimates were used to calculate the relative change in average crashworthiness of the vehicle fleet compared to year 2005 by:

$$Rel\ CWR(Year\ x) = \frac{CWR(Year\ x)}{CWR(2005)}$$

As evident from the data points in Figure 1, this trend was highly linear and was hence used to estimate the relative crashworthiness of the vehicle fleet from 2011 to 2025 assuming that the crashworthiness improvements would continue in the same way.

Crashworthiness improvements only apply to vehicle occupants so the estimated effects of vehicle safety improvements on overall fatalities and serious injuries were estimated by applying the proportionate improvements in vehicle crashworthiness from 2005 to that component of the overall trend that were vehicle occupants, typically around 85% of deaths or serious injuries. In estimating projected future impacts of vehicle safety improvement it has been assumed that vehicle occupants continue to represent 85% of deaths and serious injuries.

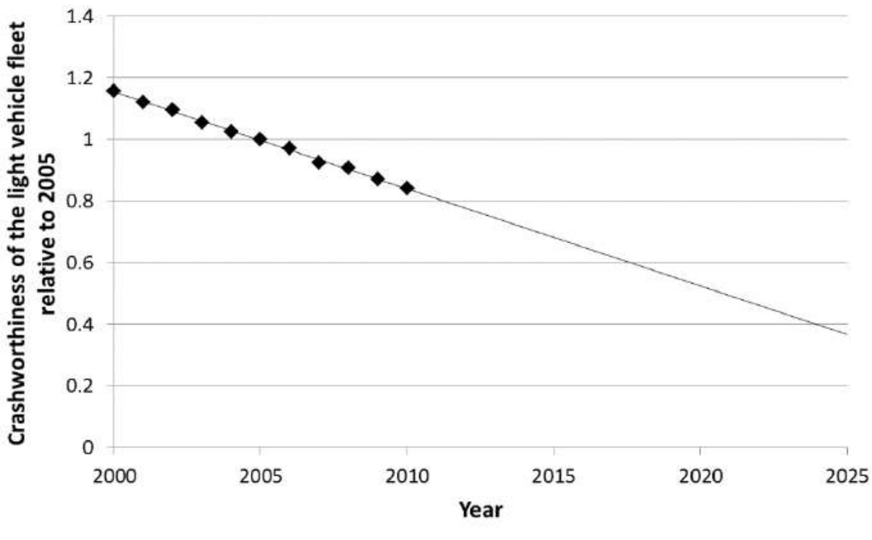

Figure 1: Average crashworthiness of the light vehicle fleet relative to 2005

Estimating SRIP effects

Effects of the SRIP program on past and expected future fatalities and serious injuries were estimated from the results of the evaluations of SRIP Stages 1, 2, and 3 (Budd, Newstead & Scully, 2011; Budd, Scully & Newstead 2011a, 2011b), and in particular estimates of program cost effectiveness in conjunction with past and planned expenditure on SRIP and estimates of SRIP treatment average lifetimes. Figure 2 shows the actual annual expenditure on SRIP from 2005 to 2014 along with the planned expenditure from 2015 to 2023. Past expenditure on SRIP has been based largely on the traditional black spot methodology for site selection apart from some small expenditure on potential blackspots. The TAC advised that SRIP expenditure from 2013 will include a component of what it terms Safe System expenditure on mass action programs expected to reduce crash frequency by at least 85% with a benefit to cost ratio of at least 1.5. Although a benefit to cost ratio for Safe System expenditure has been estimated the expected cost effectiveness of the Safe System expenditure corresponding to the estimated BCR has not been estimated but has been derived from the BCR figure based on the relationship between cost effectiveness and BCR estimates from the evaluations of SRIP (Budd, Newstead & Scully, 2011; Budd, Scully & Newstead 2011a, 2011b). Figure 2 shows the proportion of future funding allocated to Safe System expenditure.

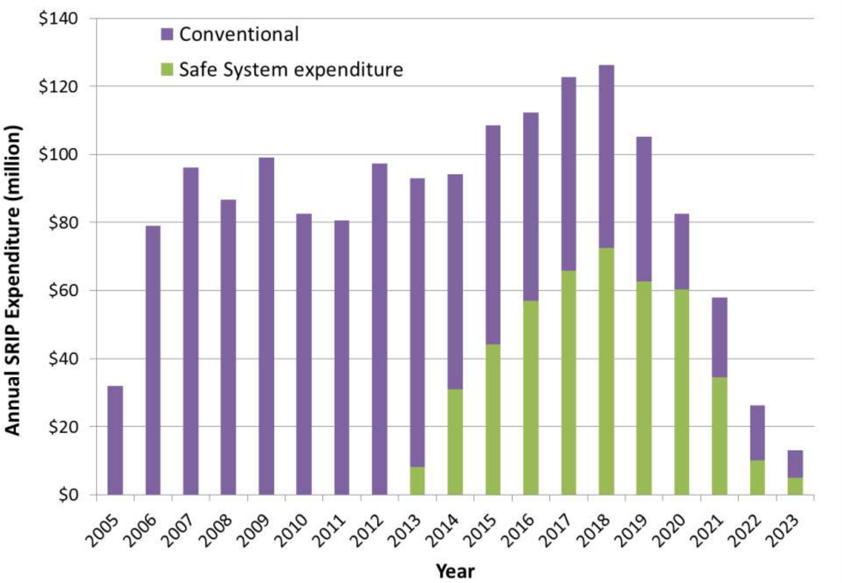

Figure 2: *SRIP expenditure: actual 2005-2014, planned 2015-2023 (Source: TAC)*

Cost effectiveness estimates from evaluation give the amount spent on the program to save each serious injury crash and fatal crash over the life of each treatment. Table 1 presents the cost effectiveness estimates for SRIP derived from the evaluations undertaken (Budd, Newstead & Scully, 2011; Budd, Scully & Newstead 2011a, 2011b). The program benefit to cost ratio is also given for comparison. No cost effectiveness estimates for fatal and serious injury crashes were available for the SRIP3 evaluation (only for all casualty crashes). For this study, an average of the cost effectiveness estimates for SRIP 1 and 2 were taken. An average benefit to cost ratio was also taken across the three SRIP evaluations. Cost effectiveness values were derived for the Safe System treatments based on the difference between the benefit to cost ratios between the regular SRIP treatments and the Safe System treatments (assuming the BCR of 1.5 which is an estimate unsubstantiated by formal evaluation) according to the following formula assuming that the cost effectiveness estimates will be inversely proportional to the benefit to cost ratios:

$$CE_{Safe\ System} = CE_{Regular\ SRIP} \frac{BCR_{Regular\ SRIP}}{BCR_{Safe\ System}}$$

Table 1: *SRIP evaluation cost effectiveness estimates*

	CE Fatal	CE Serious Injury	BCR
SRIP1	$913,036	$115,036	2.1
SRIP2	$960,294	$71,823	3.6
SRIP3	-	-	2.4
Average	$933,690	$96,150	2.6
Safe System Treatments	$1,611,745	$165,975	1.5

Crash based cost effectiveness estimates were transformed into person based cost effectiveness estimates by dividing the fatal crash and serious injury crash based cost effectiveness estimates by the number of fatalities per fatal crash and serious injuries per serious injury crashes estimated from the SRIP crash data. The person based cost effectiveness estimates were then transformed into annual fatality and serious injury savings by dividing the total SRIP expenditure in each category by the corresponding person based cost effectiveness estimates and dividing by the average treatment lifetime for treatments undertaken in that year (reflecting that the cost effectiveness figure is derived from the total capital expenditure and maintenance costs divided by total trauma savings over the life of the treatment). Table 2 gives the cost weighted average SRIP treatment lifetimes for SRIP1, 2 and 3 treatments implemented in each year from 2005 to 2010. The cost weighted average is the average treatment life for each treatment with each treatment weighted by the proportion of the total SRIP expenditure in that year each treatment represented. The average treatment life across all SRIP stages and years was 19 and did not vary greatly between years. It was assumed that all future SRIP treatments will also have an average treatment life of 19 years and that the cost effectiveness of regular treatment will remain similar.

Table 2: *SRIP treatment lifetimes*

	2005	2006	2007	2008	2009	2010
SRIP1	18.46	20.57	17.31	29.06	-	-
SRIP2	-	16.09	16.94	18.57	-	-
SRIP3	-	-	16.49	18.50	18.93	18.55
Cost Weighted Average	18.46	20.41	16.98	19.60	18.93	18.55
Overall Average	18.96					

The fatality or serious injury savings in a particular year (x) are calculated by the following formula:

$$Injury\ Savings\ in\ year\ x = \sum_{x-19}^{x} \frac{SRIP\ Expenditure\ in\ Year\ x}{Cost\ Effectivness\ \times Average\ Treatment\ Life}$$

This formula was applied to regular SRIP expenditure and Safe Systems expenditure separately and the resulting savings added.

Results

SRIP and vehicle safety effects

Estimated monthly savings in deaths and serious injuries in Victoria associated with SRIP expenditure over the period 2005-2025 is shown in Figure 3. The effect of vehicle safety improvements on deaths and serious injuries is shown in Figure 1. The estimated annual reduction in deaths and serious injuries due to vehicle secondary safety improvements is around 3%. Since the crashworthiness estimates used to derive Figure 1 give the risk of death or serious injury, it has been assumed that vehicle secondary safety improvement impact deaths in the same way as serious injuries.

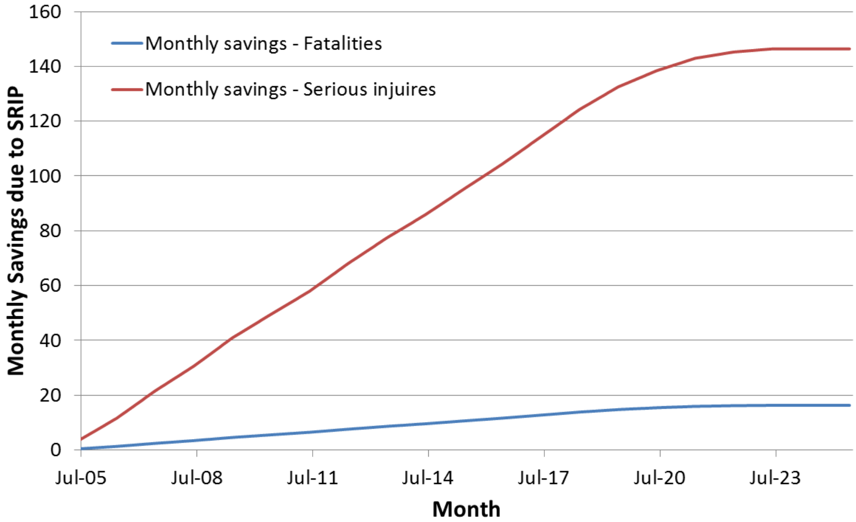

Figure 3: *Monthly savings in deaths and serious injuries due to SRIP investment: 2005-2025*

Crash data time series and forecasts

Figure 4 shows the observed monthly number of fatalities and serious injuries in Victoria over the period January 2006 to December 2014. Figure 5 shows the deaths time series alone for greater resolution.

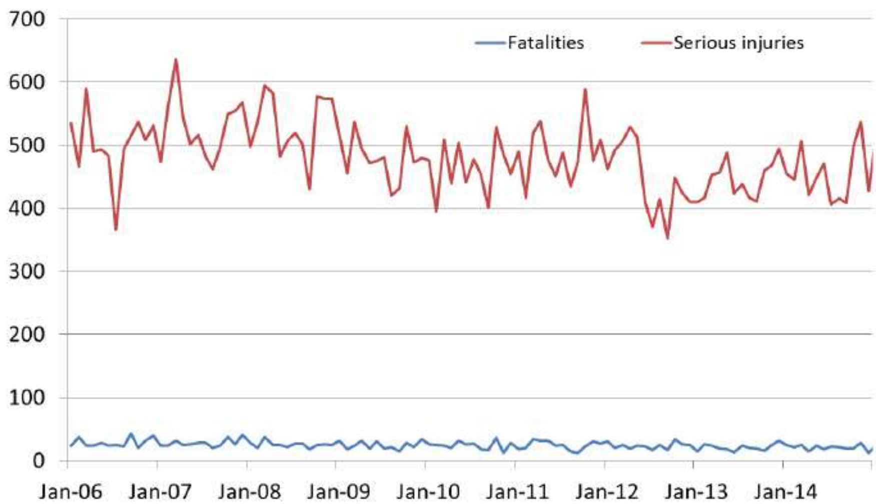

Figure 4: *Observed monthly deaths and serious injuries in Victoria: 2006-2014*

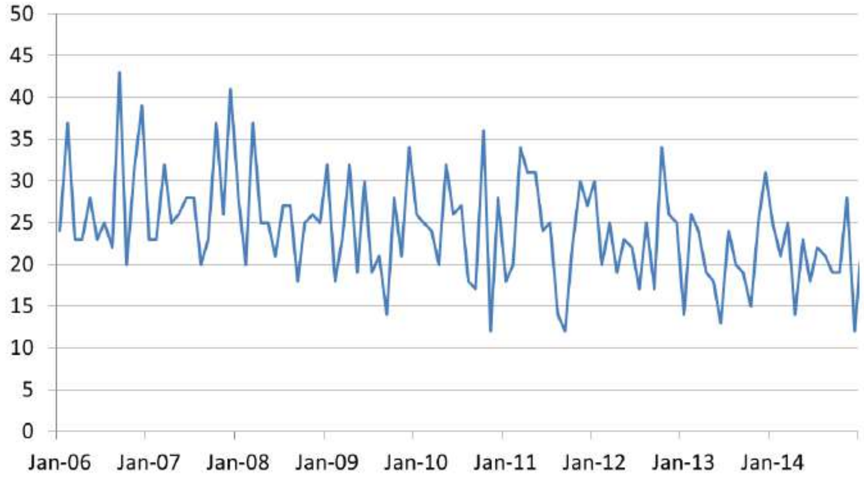

Figure 5: *Observed monthly deaths in Victoria: 2006-2014*

Figure 6 shows the effects of adjusting the effects of SRIP crash and vehicle secondary safety improvements from the serious injuries time series. The top line in the chart is the residual time series from which the time series model was estimated and the expected future trend forecast. Figure 7 shows the corresponding chart for the fatality time series.

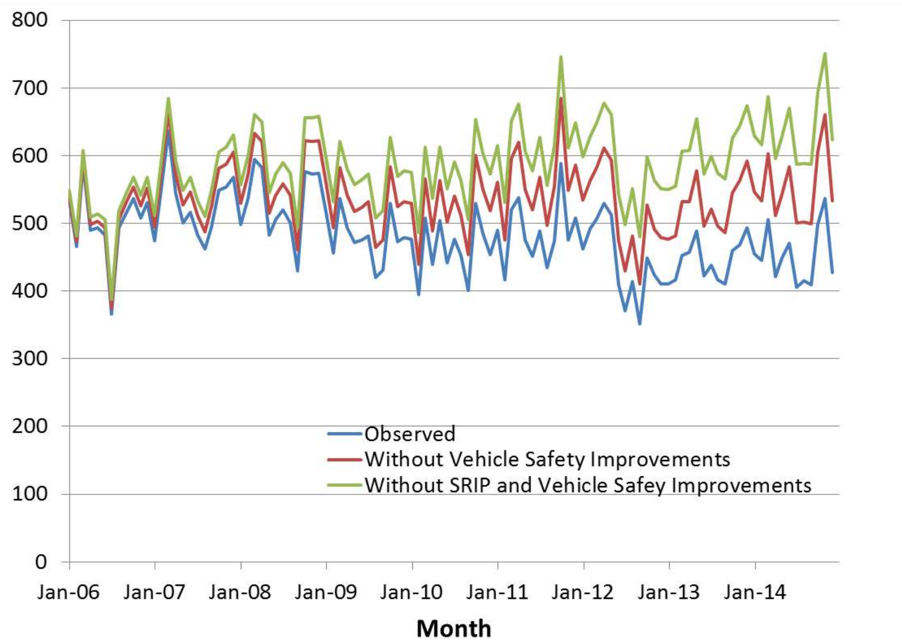

Figure 6: *Residual trend in serious injuries in Victoria after removing the effects of SRIP and vehicle secondary safety improvements*

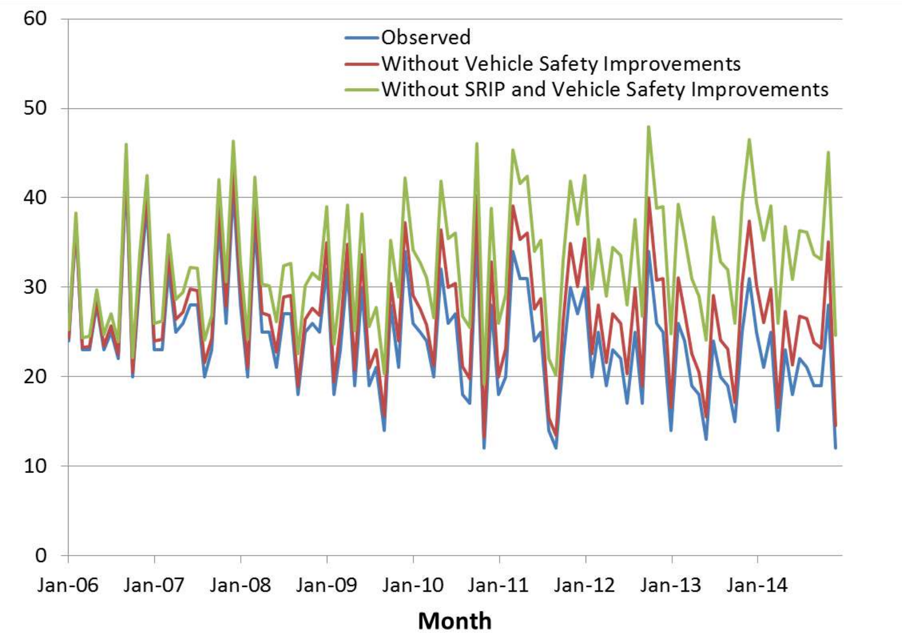

Figure 7: *Residual trend in fatalities in Victoria after removing the effects of SRIP and vehicle secondary safety improvements*

Using the structural time series model estimated from the residual serious injury trend in Figure 6, a forecast of the expected future residual trend over the period 2015-2025 was estimated. The resulting forecast is shown in Figure 8. The corresponding residual fatality series forecast is shown in Figure 9.

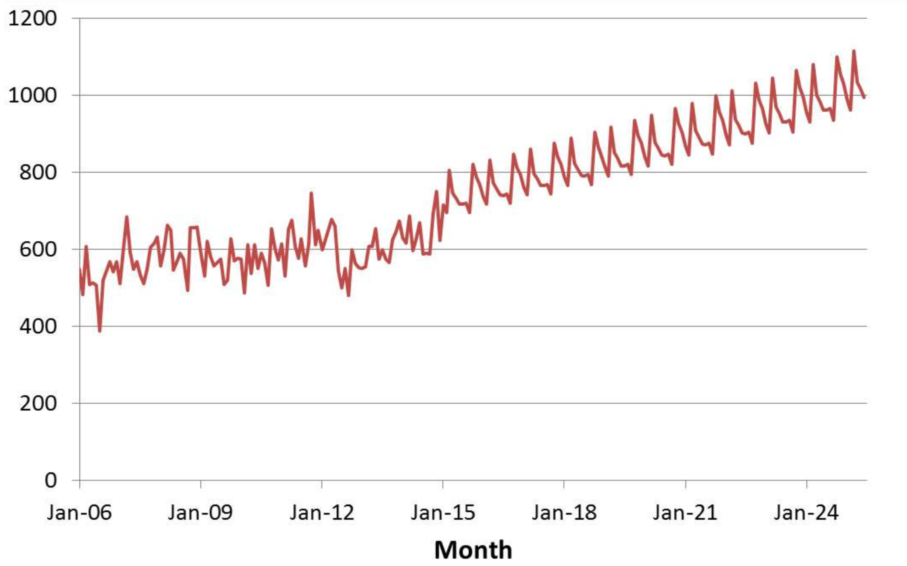

Figure 8: *Forecast residual trend in serious injuries: 2015-2025*

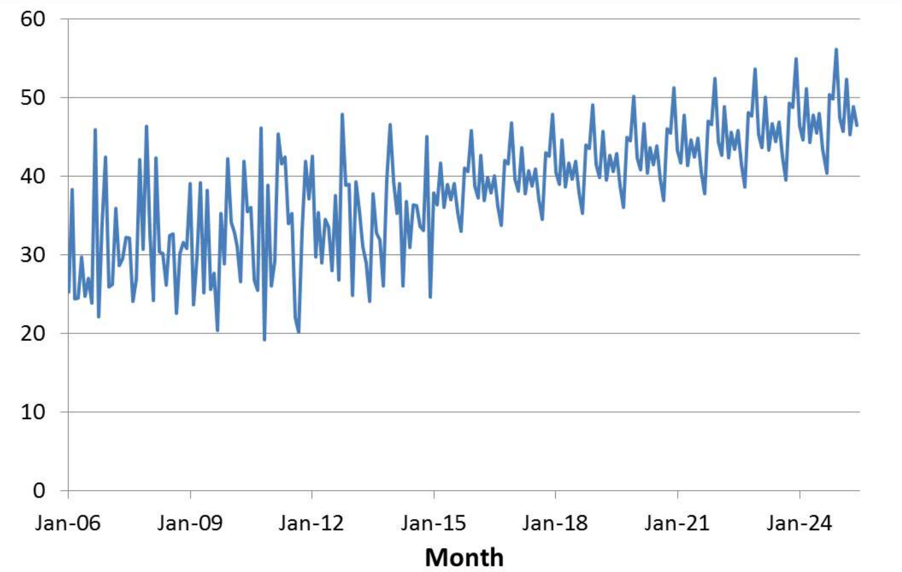

Figure 9: *Forecast residual trend in fatalities: 2015-2025*

The residual trend time series is driven by all other factors influencing road trauma apart from vehicle secondary safety trends and crash reductions attributable to SRIP. These factors might include exposure effects such as population growth; population age and gender mix; travel mode shifts (e.g. driving versus cycling, walking and public transport use); environmental (e.g. weather patterns, built environment, road environment development other than SRIP); changing behaviour (e.g. changes in alcohol use, drug use and driver distraction); and other road safety programs (e.g. enforcement, GLS, emerging vehicle primary safety technology).

Time series model forecasts were constructed on the premise that the underlying factors driving the variation in the data continue to act in the way that they have in the past. The forecasts produced for the residual fatal and serious injury time series assumes all of the factors influencing these trends, including those listed above, will continue to operate into the future either at their current static level or changing at the rate they have been changing in the past whilst continuing to influence the trauma outcome in the same way. Whether this is ultimately the case remains unknown and if any of these conditions change, the time series forecast will be compromised. It should be noted that the longer the forecast of a time series the less confidence there is in the likely accuracy of the forecast. A 10 year forecast is extremely long so confidence in the residual road trauma predictions out to 2025 will not be high.

Forecast future serious injuries over the period 2015-2025 including the effects of SRIP and vehicle secondary safety improvements are shown as the bottom line in Figure 10. Figure 11 shows the corresponding forecast fatality series with both figures showing the estimated contributions of vehicle safety improvements and SRIP expenditure.

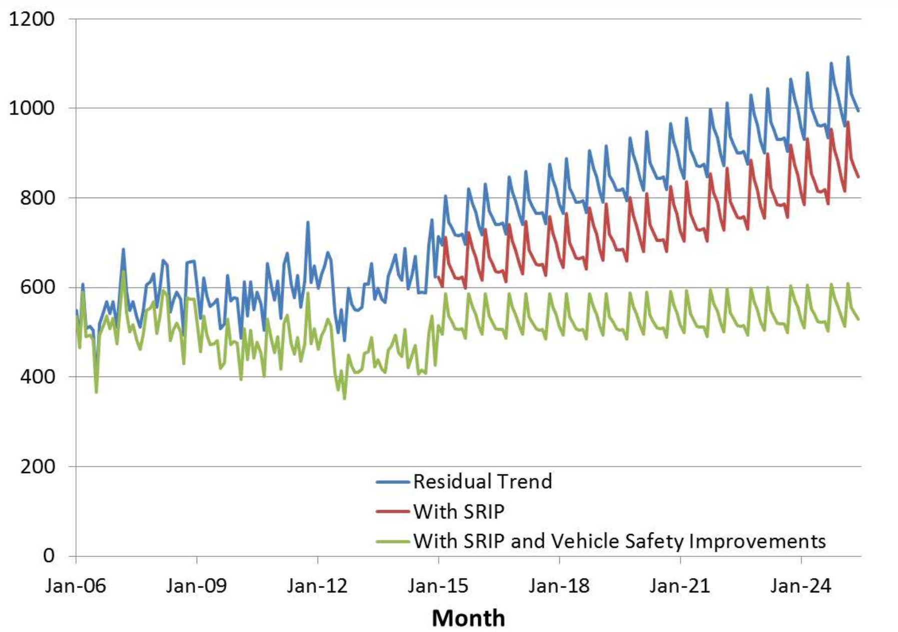

Figure 10: *Forecast trend in serious injuries including the estimated effects of vehicle safety improvements and SRIP: 2015-2025*

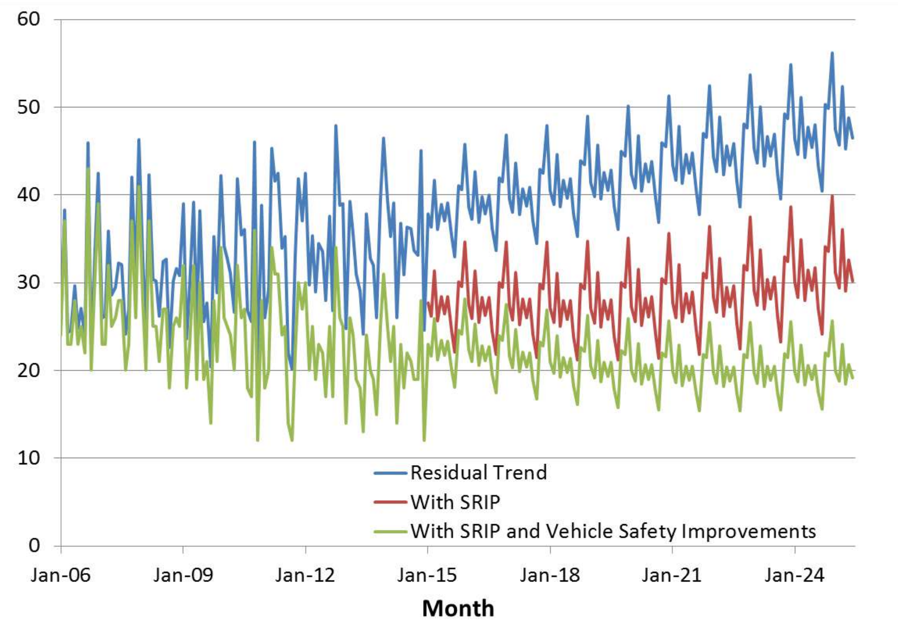

Figure 11: *Forecast trend in fatalities including the estimated effects of vehicle safety improvements and SRIP: 2015-2025*

Discussion and Limitations

This study has attempted to quantify the past and likely future impacts of two major road safety program areas, vehicle secondary safety improvement and the SRIP infrastructure program, on fatal and serious road trauma trends in Victoria. It has used existing research in the form of evaluations of Stage 1, 2 and 3 of SRIP and research estimating the impact of vehicle crashworthiness improvements, to quantify the effects of these two major, long term road safety programs. Whilst evaluations of the effects of individual road safety programs are common in the literature, research estimating the global effects of combinations of major programs on the totality of the road trauma problem is relatively novel. This project has established a methodology for undertaking this high level analysis and applied it to the Victorian context. It has demonstrated the major impact that vehicle safety improvements and SRIP investments have had in reducing serious road trauma in Victoria. Analysis has shown that without these two major programs, fatalities and serious injuries in Victoria would have continued to rise over the past decade rather than falling as observed. It also predicted that without continued future investment in these programs, fatalities and serious injuries would also rise. This is not to say that other road safety programs have made no contribution to reducing road trauma. Indeed the predicted past and future increases would be even more pronounced without any strategic road safety intervention.

Since they are based on robust evaluations of vehicle safety performance and SRIP crash effects, the contribution of these two programs to past road trauma trends is also likely to be reasonably robust. A number of assumptions underpin the estimates of the likely future contributions of these programs. Estimates of future SRIP crash effects rely heavily on the assumption that the economic worth of the SRIP program continues at the same level as for the first three stages. Given the consistency in economic worth of the first 3 stages of SRIP this assumption does not seem unreasonable however the economic worth ultimately realised will depend heavily on the continued focus on successfully identifying and treating high risk crash sites. Trends in improvement in the crashworthiness of the vehicle fleet are likely to be more robust since they have been stable over a long period and have a high degree of momentum due to the size of the fleet. Budd et al (2015) undertook some sensitivity analysis of these predictions and found that even if the improvement in the crashworthiness of new vehicles entering the fleet slowed dramatically, similar future benefits would still accrue simply due to the regeneration of the fleet. One limitation is that crashworthiness considers improvements to fatal and serious injuries equally. It is possible that fatal and serious injuries are impacted differently by vehicle safety improvements although the difference is not likely to be extremely large. It has also been assumed that the benefits of vehicle safety improvement are unaffected by the change in infrastructure quality brought about by SRIP and hence the impacts of the two programs can be considered independent. It is possible that Safe System conditions could be achieved purely through infrastructure works making vehicle safety performance redundant. However, given the scale of SRIP works and the average crash reduction effects measured for SRIP, the SRIP program is still a long way from making all Victorian infrastructure Safe System compliant. Hence it seems reasonable to assume vehicle safety effects operate largely independently of infrastructure over the past decade and for many years into the future.

As noted, the forecasts of future residual road trauma trends on which the benefits of SRIP and vehicle safety improvements were based are also based on a number of assumptions, the most important of these being that the underlying drivers of road safety performance remain the same into the future. Whether this assumption will remain valid is difficult to predict, however this will have little effect on the magnitude of contribution that vehicle safety and SRIP are predicted to make, only impacting the estimates of absolute road trauma expected without these programs

Conclusion

It is evident that improvements in vehicle safety and major investment in safer infrastructure through SRIP have been very successful in achieving significant savings in death and serious injury. However, estimated fatal and serious injury future trends indicate that the ongoing issue of serious injury trauma will require particular focus and effort by road safety policymakers to address. Whilst this work does demonstrate the effectiveness of vehicle safety improvements and infrastructure investment on preventing serious road trauma, the projected future benefits of these key road safety program areas highlight how critically important it is to continue to invest in proven road safety programs if the benefits that have been achieved thus far are to continue going forward.

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Using Smartphones for Cycling Safety: a Survey of Riders Preferences and Interest in New Technologies

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Abstract

Cyclists are among the most vulnerable road users. Many recent interventions have aimed at improving their safety on the road, such as the minimum overtaking distance rule introduced in Queensland in 2014. Smartphones offer excellent opportunities for technical intervention for road safety at a limited cost. Indeed, they have a lot of available processing power and many embedded sensors that allow analysing a rider's (or driver's) motion, behaviour, and environment; this is especially relevant for cyclists, as they do not have the space or power allowance that can be found in most motor vehicles. The aim of the study presented in this paper is to assess cyclists' support for a range of new smartphone-based safety technologies. The preliminary results for an online survey with cyclists recruited from Bicycle Queensland and Triathlon Queensland, with $N = 191$, are presented. A number of innovative safety systems such as automatic logging of incidents without injuries, reporting of dangerous area via a website/app, automatic notification of emergency services in case of crash or fall, and advanced navigation apps were assessed. A significant part of the survey is dedicated to GoSafeCycle, a cooperative collision prevention app based on motion tracking and Wi-Fi communications developed at CARRS-Q. Results show a marked preference toward automatic detection and notification of emergencies (62-70% positive assessment) and GoSafeCycle (61.7% positive assessment), as well as reporting apps (59.1% positive assessment). Such findings are important in the context of current promotion of active transports and highlight the need for further development of system supported by the general public.

Introduction

Cyclists are among the most vulnerable road users, representing 1 in 40 road crash fatalities and 1 in 7 serious injuries (Garrard, Greaves, & Ellison, 2010). Collision with motor vehicles is the leading cause of fatality and severe injuries in cyclists, which can be explained 60% of the time by a lack of awareness from either the cyclist or driver about each other (Australian Transport Safety Bureau, 2006). While the majority of incidents require the cyclist to take evasive action, the driver is responsible for the majority of events (87%) (Johnson, Charlton, Oxley, & Newstead, 2010). The developments of Advanced Driving Assistance Systems (ADAS) in recent decades have mostly focused on improving drivers' perception of their environment or on palliating their lack of reaction to critical events. As a result, such ADAS should improve cycling safety as a corollary effect, given the responsibility of drivers in collisions with cyclists. For example, heavy trucks blind spots present a significant danger for two-wheelers (Niewoehner & Berg, 2005); several research efforts are attempting to reduce this danger (Ahrholdt, Grubb, & Agardt, 2010; Aycard et al., 2011).

However, it has been claimed that car-centric technological advances have not improved cycling safety (Garrard, et al., 2010). Some empirical research has led support to this claim: for example, the blind-sport information system tested as part of EuroFOT showed no significant improvement of safety (Benmimoun, Pütz, Zlocki, & Eckstein, 2013; Malta et al., 2012).

As result, one may argue that technological intervention centred on cyclists, or equally involving cyclists and motorists, may better benefits riders' safety (Andreone & Wanielik, 2007). Cycling near an intersection can increase crash risk as much as twelve times if vision is impaired by buildings or vegetation (Dozza & Werneke, 2014); a system such as proposed in Thielen, Lorenz, Hannibal, Koster, and Plättner (2012) uses technology to help reduce this risk to a more acceptable level via direct cooperation between motorists and cyclists.

The ubiquitous nature of smartphones in advanced economies such as Australia—8.7 million users in 2012 (ACMA, 2013)—means that such devices are excellent candidates to extend ADAS-like technological intervention to cyclists (Du et al., 2012; Picone, Amoretti, & Zanichelli, 2012; Voigtmann, Lau, & David, 2012). The main proposed approach is to use smartphones' sensors (GPS, accelerometers) and communication capabilities (e.g. Wi-Fi) to share position and velocity data between vehicles and cyclists, allowing to predict crashes (Liebner, Klanner, & Stiller, 2013; Thielen, et al., 2012). Another approach is the detection of incidents and crashes, a form of eCall for cyclists (Candefjord et al., 2014). Additionally, smartphone-based cycling safety applications could also be used to collecte cycling naturalistic data (Dozza & Werneke, 2014), providing further indirect benefits. However, such claims should be mitigated by the risks of increased distraction using mobile devices (de Waard, Schepers, Ormel, & Brookhuis, 2010; Ichikawa & Nakahara, 2008; Stelling-Kończak, Hagenzieker, & Wee, 2015).

The goal of this study is to assess riders' interest and support for smartphone-based systems aimed at cycling safety, and to capture their willingness to use these systems and their trustworthiness. In this paper, the preliminary, principally qualitative, results of the study are presented. An online survey was conducted during the first semester of 2015, with 191 respondents recruited among the membership of cycling organisations Bicycle Queensland and Triathlon Queensland (more detailed results will be presented in a future paper).

This study can be used to evaluate the public support and demand for cycling safety technologies, as well as orient resources toward desirable technologies. Its results, and subsequent technologies development, could also have applications outside of road safety itself, as the perception of cycling as a highly risky activity is known to decrease participation (Goldsmith, 1992; Griffin & Haworth, 2015; Heesch, Sahlqvist, & Garrard, 2012). However, it should be noted that riders' perception of the improved safety provided by cycling technology may not match the actual safety benefits offered by such applications.

Method

The survey aims to capture data on both riders' current smartphone usage for cycling (e.g. for navigation) and their willingness to extend this usage to more advanced safety-orientated functions. The survey was designed online using the KeySurvey software, and consists of 80 items divided in three main parts. The survey was approved by the Queensland University of Technology Research Ethics unit under number 1400000769. A general overview of the questionnaire is given in this section; more details are laid out for each specific question addressed in the results section.

The first part consists of items specifically geared at assessing the sample exposure to (1) riding, and (2) smartphone usage in relation to riding. The questions pertaining to cycling exposure are taken from the European COST Action TU1101 survey (Bogerd et al., 2012). Some questions also assess the participants' perceived safety while riding. This part covers 50 items, not all common to all respondents: for example, respondents that used smartphones would be asked which general category of applications they use, then which specific apps in those categories (both with prompted answers and free text "others" answers). The last item in this first part asks participants about their interest (on a 7-point Likert scale) for 8 new technologies for cycling safety. Participants cannot skip this section, but can skip individual questions within it (information about skipping rate is given in the results section where relevant)

The second part, containing 19 items, is specifically focused on GoSafeCycle. GoSafeCycle is a smartphone application currently under development at CARRS-Q that aims at providing a fully decentralised safety network for cyclists and drivers through a form of peer-to-peer cooperation. Thielen, et al. (2012) have proposed a similar application, but it depends on dedicated ITS communication infrastructure, and particularly on motor vehicle-centric communication technologies that are believed to be available to consumers within 10 to 20 years only (Hammer, 2014). GoSafeCycle solves this problem by offering a fully decentralised approach where the smartphone is the only required piece of equipment. Riders and drivers run the app on their smartphone while using their vehicle and the app automatically forms a wireless ad-hoc network (Hartenstein & Laberteaux, 2009) using a derivative of Wi-Fi technology called Wi-Fi Direct (Camps-Mur, Garcia-Saavedra, & Serrano, 2013; Satish, 2014). The questions probe the respondents' interest in the app, and how trustworthy they believe it would be. A number of items also concern different preferences regarding how to parameter the app, what information it should display, and more importantly the feedback mechanism preferred in case of danger. Participants are allowed to skip this section entirely.

The third part, also made of 19 items, focuses on other advanced cycling technologies that could be developed in the future (including automatic detection of crashes or falls, blind-sport warning, and incident/road defect logging). The first item is similar to the last item of the first part, probing interest on a 7-point Likert scale in those new technologies, however the list differs slightly to focus on functionalities that have a shorter deployment timescale and could be developed entirely on smartphones. Participants are asked to rate their trust into a fall detection app that can automatically notify their families, and how using this app would influence their perceived riding safety. A few questions investigate applications to report incidents or road defects, and how likely the respondents would be to use them to send information to the appropriate stakeholders. Finally, this part concludes with a question on cycling-focused navigation apps (aimed at the Bikeway app, http://www.strc.com.au/research-portfolio-2/projects/ developed by QUT's STRC). Participants cannot skip this section.

Participants were recruited through outreaches in the publications and social media accounts operated by Triathlon Queensland and Bicycle Queensland. The present paper is based on the results collected as of May 1st, 2015, with a total of 191 participants: the confidence interval obtained for this sample size is $CI = 1/\sqrt{191} = 7.2\%$. No specific requirement was placed on the participants; it is likely to be biased toward experienced and engaged cyclists as a result of the recruitment method.

The sample is largely male (78%), aged 20-76 ($M = 47.14, SD = 11.01$). 76 (40%) have children under the age of 18. 187 participants indicated living in Queensland. 183 (96%) participants said they owned at least one smartphone; 91 (50%) have Apple handsets, 82 (45%) had Android-based handsets (brands such as HTC, Samsung, or Sony Ericsson). All participants own at least bicycle, and all have a current light vehicle driving licence. A third of the sample (85 respondents) also has a motorcycle driving licence. Respondents were relatively experienced drivers, having held on average their licence for 28.7 years ($SD = 11.57$); the oldest license was 58 years old. There was no requirement that the participants be 18 years of age at least, but no underage person took part in the survey.

Results

Participants cycling exposure

In the first part of the questionnaire, participants were asked about their cycling habits. Table 1 presents the results for the most commonly ridden type of bicycle, and the frequency of riding (190 respondents, 1 skipped). The most common bicycle type is road, and more than 60% of the respondents rode a few times a week on average, but not daily. 87% of the participants with minor children indicated that their children ride bicycles.

A very important part of this first section for our study relates to the perception of safe riding. As shown in Table 2 (5-point Likert scale with 176 respondents, 15 skipped), a majority feel moderately safe (48%) or safe (13%) while riding, overall. In a follow-up question, respondents were asked what made them feel unsafe (a list of answers was presented, with a free-text “other” option, and multiple answers possible): motorist behaviour was flagged by 95%. Table 4 (174 respondents, 17 skipped, multiple answers possible) shows the result for the next question assessing which motorists’ behaviour were unsafe, or perceived as such; most common reported are passing too closely, cutting the rider off, and entering an intersection without looking

Table 1. Bicycle use and riding frequency

Most commonly ridden bicycle	**Number of respondents**	**Percentage of respondents**	**Frequency of riding (over the last 12 months, null answers removed)**		
			Daily	A few times a week	A few times a month
Road	142	74.7%	23.2%	65.5%	11.3%
City/hybrid	21	11.1%	47.6%	38.1%	14.3%
Mountain	16	8.4%	12.5%	75.0%	12.5%
Electric	3	1.6%	66.6%	33.3%	0.0%
City-sharing scheme	0	0.0%	N/A	N/A	N/A
Other	8	4.2%	50.0%	50.0%	0.0%

Table 2. Perception of cycling safety

Overall safety rating while riding	**Response percent**
Moderately safe	48.3%
Moderately unsafe	19.9%
Neutral	17.1%
Safe	12.5%
Unsafe	2.3%

Table 3. Unsafe behaviours from motorists (or vehicle occupants)

Motorist and vehicle occupants behaviours that made riders feel unsafe (prompted answers)	**Response percent**
Passing too closely	92.5%
Cutting the rider off	73.0%
Entering an intersection without looking	64.9%
Opening a door without checking	54.6%
Nearly hitting the rider	54.0%
Honking at the rider	41.4%
Driving too fast	37.9%
The mere presence of vehicles made the rider feel unsafe	4.0%

Other	16.1%

Usage of cycling technologies and smartphones

Just over half of respondents (51%) said they were not using their phone while riding (8 skipped the question). Respondents indicated they usually have their phone in a pocket (68%) and/or in a bag (36%), only 6% said they had their phone mounted on the handlebar. The most widespread use of smartphones was for recording information related to travel and fitness (40%), using apps such as Strava (54 respondents), MapMyRide (17 respondents), or Garmin Fit (15 respondents). 16% use their phone for navigation, using predominantly Google and Apple Maps (24 and 6 respondents respectively), although many different fitness apps were also reported to be used for this purpose (16 such respondents). People were generally aware that data was being collected by those apps, and almost all said they were able to review those data later on the apps or linked websites (e.g. reviewing your trips with Strava).

A majority (64%) replied “yes” to the question “*do you feel the current technologies you are using provide for all your needs*”. Respondents that said no (68 people) to the latter were asked what would they like to see improved, the answers were fairly spread around: see table 4 for details.

Table 4. Improvements in existing technologies

What could be improved for currently existing cycling technologies (prompter answers, multiple answers possible)	Response percent
Impact on battery life	57.4%
Ease of use	36.8%
Ergonomics	33.8%
Accuracy	26.5%
Availability on more devices	26.5%
Geographic coverage	20.6%
Other	32.4%

Participants were also asked (190 respondents) what other technologies than those mandated by law (lights) and smartphones they were using; most people (73%) indicated using some other technology. The majority was a non-phone-based GPS device (57%); 22% said they were using cameras.

Interest in new cycling technologies

The first question related to interest in new cycling technologies asked participants to rate their interest in a number of proposed functions from “very low” to “very high” on a 7-point Likert scale. The functions are either infrastructure-based solutions, or mobile phone ones (the question includes a brief description of the technology if its nature is not obvious). The detailed results are shown in Figure 1.

Five applications on the 8 proposed gathered more than 50% of positive responses, from 59% to 78%. The most positively received proposed function is intelligent traffic lights, i.e. lights that can dynamically change from red to green to let cyclists pass if there is no incoming traffic at an intersection; 42% of the respondent said they were very highly interested in it, and it had a total of

78% positive interest. The second function with the most "very high" interest is collision prevention with motor vehicles, although it is only the fourth most positively received application overall.

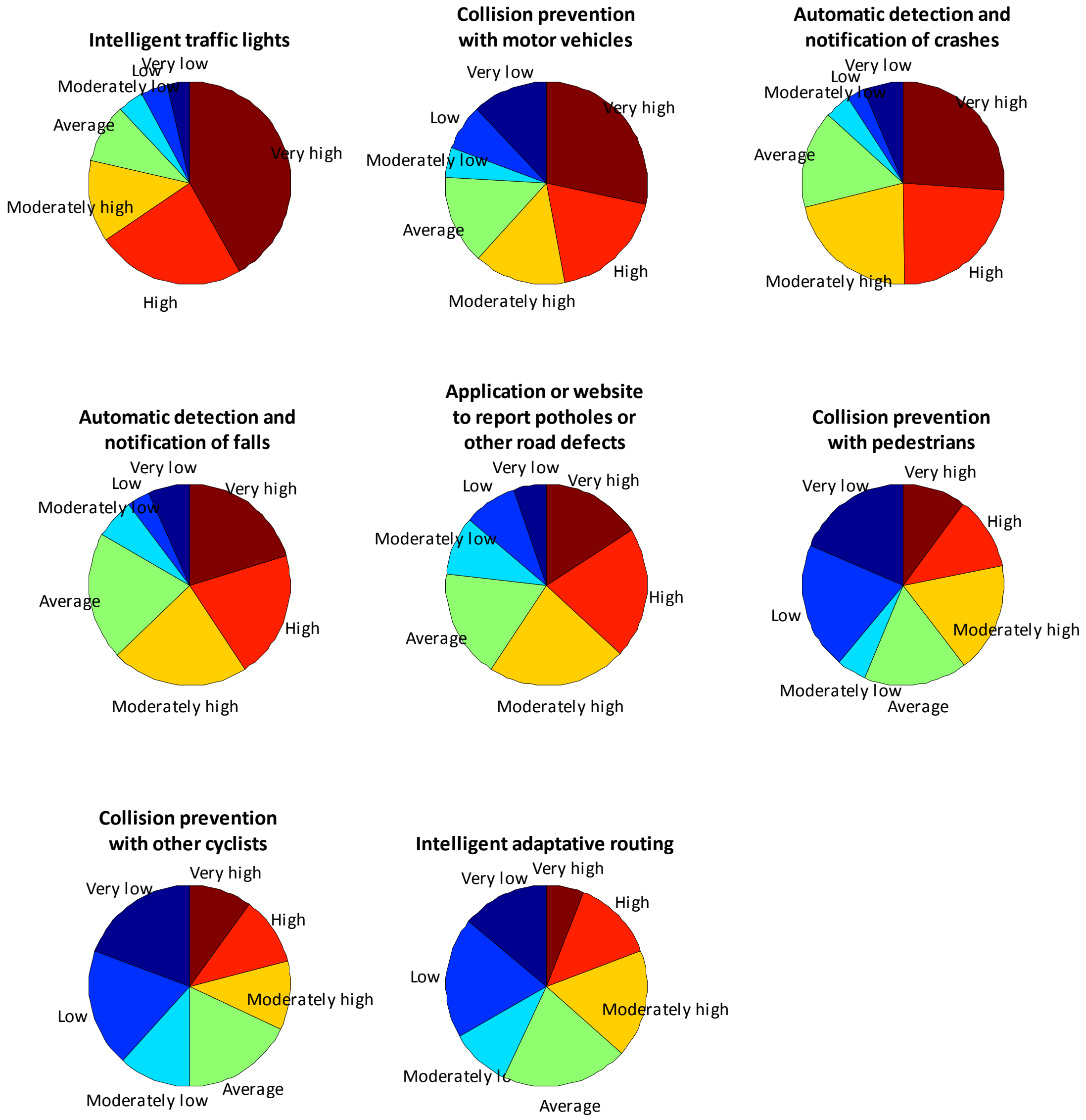

Figure 1. Interest expressed for 8 new cycling technologies

GoSafeCyle

76% of the participants accepted to answer questions about the GoSafeCycle app after they were presented with a 1-page presentation of how the app worked and what it hopes to achieve (including a screen capture of the current interface). In the rest of this subsection, percentages are given relative to those respondents (145 over the 191 total).

Table 5. Trust placed in GoSafeCycle

Trust placed in GoSafeCycle	Response percent
Average	28.3%
Low	18.6%
Very low	17.2%
Moderately low	16.6%
Moderately high	15.2%
High	3.5%

Very high	0.7%

The majority of respondents (52%) said they would have low trust in the safety function provided by GoSafeCycle; a third rated it average, and only 19% would have trusted it, see Table 5 for the 7-point Likert scale. 60 participants rated the app regarding the safety of their children: a short majority of 55% said they did not believe it would improve their children's safety.

80 respondents (55%) said they would be willing to use the app as pedestrians, when it provides no immediate benefit to them but help relay information to cyclists and motorists nearby. The majority did not believe that bundling the pedestrian version of the app with a music player would make them more likely to participate. Battery life (66%, 42 respondents) and privacy issues (41%, 26 respondents) are cited as concerns about using the pedestrian version, as well as forgetfulness (37%, 24 respondents). This question generated a lot of "other" answers (33%, 21 responses), ranging from distraction, data overload, or that the respondent was rarely walking around.

Most of the other questions concerning GoSafeCycle were aimed at gathering preferences in terms of user interface and accessible data. Table 6 summarises the results of a 5-point Likert scale rating (useless to useful) of the different possible feedbacks to warn the rider of an impending collision; for easer interpretation, they are consolidated into a 3-point scale rating (positive, neutral, and negative). Three possible types of feedback are possible: visual, sound, and haptic. Those were proposed individually, and in a variety of combinations. Respondents seem to prefer sound-based notifications, alone or in combination with any other feedback mechanism. A visual-only system was rated 65% negatively, as well as a haptic-only one. The most positively rated feedback proposal is the combination of the 3 mechanisms at once, with 70% of positive ratings. Interestingly, respondents seemed unable to decide how to rate a combination of visual and haptic feedback without sound, roughly spread a third each.

Most respondents (59%) said they would prefer their phones to be mounted on the handlebar for the app to work, although about a third also liked to be able to keep their phone in their pocket or bag and still use the app.

Table 6. Consolidated ratings for various feedback mechanisms

Proposed feedback	Positive ratings	Neutral ratings	Negative ratings
all	69.8%	16.5%	13.7%
Sound	68.6%	12.9%	18.6%
Visual and sound	67.2%	11.7%	21.2%
Sound and haptic	57.1%	20.0%	22.9%
Visual and haptic	26.1%	34.1%	39.9%
Visual	22.0%	13.5%	64.5%
Haptic	20.0%	15.7%	64.3%

A 61% majority believed that it would be preferable that the GoSafeCycle's display is only active when one interacts with the phone, rather than at all time. A shorter majority of 56% preferred the phone to be locked by the app for any potentially distraction use, providing it would not interfere with other apps being used in the background such as fitness recording apps.

In Table 7, the results for questions surrounding the information conveyed by GoSafeCycle to the riders are shown; consolidated 3-point ratings are used here too, the original questions used a 5-point Likert scale (useless to useful). The three rows highlighted in grey are safety parameters, whereas the others are information of potential convenience to the riders. It appears that displaying safety information such as the probability of collision or the Time to collision (TTC) was largely rejected, with 46-53% of negative ratings. On the other hand, displaying convenient information about the rider's trip, such as the speed and travelled distance, or integration with navigation app, were positively rated by more than 70%.

Table 7. Consolidated ratings for information to display on GoSafeCyle screen

Proposed information to display	Positive ratings	Neutral ratings	Negative ratings
Probability of collision	38.6%	14.5%	46.9%
Evasive suggestions	36.0%	16.6%	47.5%
Time to collision	32.4%	14.5%	53.1%
Current speed	76.6%	12.4%	11.0%
Travelled distance	76.6%	11.0%	12.4%
Travelled time	72.5%	14.1%	13.4%
Integration with navigation functions	70.6%	18.2%	11.2%
Nothing but safety information	11.6%	56.6%	31.8%

Respondents were 83% (121 respondents) in favour of the app's users being able to tweak the app's parameters, both for the display and the safety parameters, as long as a minimum safety level was always provided (as suggested in the question). Further details are shown in Table 8 (120 respondents, 25 skipped); same consolidated scale as in Tables 6 and 7. The most popular parameter was the risk threshold to be used by the app before triggering the alarm, basically allowing riders to set a preference level for risk-taking. Least popular parameters revolved toward the social aspect of the application, 26% having a negative opinion on the possibly to enable connection notifications, and only 52% a positive one. Other social aspects (such as being able to see if your friend use the app and are connected to you while riding) received generally neutral to slightly positive responses too.

Table 8. Consolidated ratings for proposed tweakable parameters

Proposed tweakable parameter	Positive ratings	Neutral ratings	Negative ratings
Risk threshold to trigger the alarm	80.0%	12.5%	7.5%
Information displayed on screen	76.5%	13.5%	10.1%
Amount of time before alarm	74.2%	14.2%	11.7%
Connection distance to other devices	65.3%	19.5%	15.3%
Parental tracking	60.2%	23.7%	16.1%
Connection notification	51.7%	22.5%	25.8%
Children mode (increased safety)	50.8%	30.0%	19.2%

Discussion

Firstly, it is important to note that a limitation of the current study is the nature of its sample, currently biased toward experimented cyclists from South-East Queensland; regional differences exists in the type and rate of cycling in Australia, e.g. for cycling to work (Bell, Garrard, & Swinburn, 2005). If the same survey was conducted in, for example, Melbourne, the perception on the usefulness of GoSafeCycle and related apps may vary. The same apply for more casual riders.

Several technologies had a “high” or “very high” interest rating among participants, first among them traffic light system that can allow cyclists to cross intersections if no car is present (or a related system like Traffic Eye Zurich that gives priority to cyclists at intersections: http://www.mobycon.com/page/428/traffic-eye-zurich.html). Collision prevention with motor vehicle was the second most positively received system. In this section, the focus will be on GoSafeCycle and apps for collision prevention; the other technologies proposed will be discussed in further details in another paper due to lack of space and the preliminary nature of this survey.

As expected, almost all respondents claimed that motorists’ behaviour made them feel unsafe at some point while riding. Two of the three most cited unsafe behaviours were cutting the rider off (73%) and entering intersections without looking (65%) (the other and most cited was passing too closely) A collision prevention app like GoSafeCyle or the one from Thielen, et al. (2012) would be relevant in such scenarios, especially the latter; by using it, cyclists would signal their presence to motorists approaching intersections. This was recognised by the respondents: collision prevention with motor vehicles was the second most popular application among the 8 sampled, and participants gave a positive rating 62% of the time when asked specifically about GoSafeCycle. A desire for some technological intervention appears to be present among the participants, which is also found in Cardamone, Eboli, Forciniti, and Mazzulla (2014).

However, trust in the technology’s efficiency appears to remain an issue for cyclists. Indeed, the relatively positive sentiment about the app is balanced by a majority (52%) of distrust in its efficiency among the participants, and a higher rate of very negative ratings compared to the other applications. One may argue that this lack of trust stems for the fear of unnecessary distraction (for both riders and motorists), which was noted in open text comments and also found by Cardamone, et al. (2014) in relation to mobile applications for road safety. Stelling-Kończak, et al. (2015) found that self-reported cycling risk and performance were negatively influenced by mobile phone usage while riding (including by listening to music); many other studies point out the distracting effect of mobile phone usage on cyclists (de Waard, et al., 2010; Ichikawa & Nakahara, 2008). Fear of distraction during critical events may explain why non-critical information (e.g. speed) displayed on the app’s screen were generally received positively, but not critical information (e.g. the time to collision).

An important outcome of this survey is that half of the participants reported currently not using their phone while riding and two-third of those using it believe that the current technologies already provide for all their needs. This result limits the scope of users for GoSafeCycle and related apps, at least in term of the reported usage of smartphones and the potential intention to use them. However, there is no obvious rejection of cycling technology since 73% of participants use some form of it, mostly non-phone GPS devices or cameras. This means that if trust in GoSafeCycle (or similar apps) could be improved, there is no fundamental issue with having riders adopt it in greater numbers.

Acceptability and improving trust in a collision prevention app is thus likely to improve its market penetration and, as a result, cycling safety. According to a variation of the Technology Acceptance Model developed by Kaasinen (2005), four factor will influence acceptability of mobile applications, and thus penetration: perceived value, perceived ease of use, trust, and perceived ease of adoption. Another model (Koivumaki, Ristola, & Kesti, 2006) cites usefulness, user guidance and support, and user skills.

One current limitation to the perceived value, as well as the high lack of trust, may be related to the fact that motorists are more to blame for cycling crashes (Johnson, et al., 2010). So one possibility to improve the app acceptability may lie in making it somewhat more car-centric, or at least provide increased functionality to counter distraction and lack of awareness of cyclists in motorists. For example, one could imagine the motorist version of GoSafeCyle would use passive functions to detect vulnerable road users via their phone's Bluetooth and Wi-Fi even if they are not actively using the app (Ruppe, Junghans, Haberjahn, & Troppenz, 2012); this would provide a crude mechanism to track the number of cyclists in certain areas (notably at intersections) and warn motorists that they need to increase their awareness—see also Castronovo, Endres, Del Fabro, Schnabel, and Müller (2011). GoSafeCyle's value for cyclists would thus be significantly improved.

Tailoring applications to the needs and preferences of users may affect the ease of use, user support, and, to some degree, the perceived value. The feedback mechanism used in emergency is one such aspect. The preference for sound feedback (and combinations of other mechanisms that feature sound) is similar to results obtained in Italy for motorists (Cardamone, et al., 2014). In that study, sound was preferred to other feedback because sound is "faster and safer", and visual feedback would be a source of distraction; research has shown (Scott & Gray, 2008) that sound feedback is better than visual one, but not as good as tactile (haptic), for safety critical information. However, Stelling-Kończak, et al. (2015) and De Waard, Edlinger, and Brookhuis (2011) note that auditory distraction is also possible for cyclists in relation to mobile phone usage, so the app's feedback needs to be carefully controlled.

Another finding was that that risk threshold triggering a collision alarm was the most popular tweakable parameter proposed, allowing riders to set a preference level for risk-taking, or alternatively reduce the likelihood of nuisance in case of recurrent alarms. Alarm timing was found to be a contributing factor to driver trust in a collision-warning application by Abe and Richardson (2006); this can likely be extended to cyclists. Furthermore, only a small proportion of emergencies detected by the system may result in actual emergencies (Parasuraman, Hancock, & Olofinboba, 1997). The popularity of the aforementioned parameter may stem from an underlying understanding of this issue. Finally, only 32% thought the Time to Collision (TTC) was useful information to display on the app's screen. This is in contrast to the usage of TTC as fundamental information in most car-centric ADAS (Vogel, 2003); the reasons for this lukewarm rating should be investigated.

Conclusion

The results of this preliminary study show that cyclists are generally in favour of smartphone-based application aimed at improving their safety. However, it also shows that they are not, at the moment, placing any significant trust in an app like GoSafeCycle. The reasons for that dichotomy may stem from a fear of distraction and a lack of demonstrated safety results for such apps. Riders strongly preferred to display non-safety related information on their device, and also responded positively to a system that would detect and notify crashes or solo-incidents. In a future paper, more extensive results will be presented and discussed, notably regarding the other new functionalities (e.g. automatic incident reporting) that were investigated in the online survey's last part. The sample size will be over 200 respondents, following a second recruiting campaign via the mainstream media.

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‘Learn, Drive, Survive: Drives for Learners in the Moreton Bay Region’ (Queensland) – A practical tool for Supervisors and Learner Drivers

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Abstract

A practical and collaborative approach has been undertaken to develop and implement phase one of the ‘Learn, Drive, Survive - Drives for Learners in the Moreton Bay Region’ booklet. Based on fatality and injury statistics as well as research that identified the need to develop the skill and knowledge base of drivers in the learner licensing stage, the booklet of driving routes and road safety information provides an educational tool for supervisors and learner drivers. Building and expanding on a road safety initiative from NSW the booklet provides a total of 13 routes covering the Moreton Bay Region in Queensland. The routes contain a variety of drives across the region including different road types, driving conditions and from rural to urban. Each drive has detailed instructions, maps and all the details required to complete the Queensland learner driver log book. The booklet creates access, ideas and opportunity for valuable on-road driving time and experience for learner drivers working towards accrual of the 100 hour minimum state government driving requirement to obtain a provisional licence (P1). Partnering with the Department of Transport and Main Roads (TMR) and working with Queensland Police Service (QPS) provided important linkages of knowledge and expertise in the development of the booklet. Launched in December 2014 over 8,000 copies of the booklet have been distributed across the region.

Introduction

The 'Learn, Drive, Survive - Drives for Learners in the Moreton Bay Region' booklet links with the Graduated Licensing Scheme (GLS) that has been operational across Queensland since 2007 by providing opportunity for learner drivers to accrue credible driving time toward the 100 hour minimum on-road supervised driving time requirement. The booklet is aimed at providing practical options for learner drivers to gain as much on-road supervised driving experience on roads throughout the Moreton Bay Region whilst in the learner licensing phase. Young drivers are one of Queensland’s most ‘at risk’ road user groups and account for approximately 13% of all licence holders. An abundance of research illustrates a range of factors that contribute to crashes involving young drivers including inexperience, inattention, over confidence, less developed visual/perceptual skills, deliberate risk taking, alcohol/drugs and limitations in responding to risks or hazards whilst driving.

Queensland’s road crash data (Webcrash) identified that during the 2009-2013 period, 27% of drivers and riders in the Moreton Bay Region were aged 17-24 years, where age was known. Of these casualties 14 were fatalities and almost 1405 were hospitalised or required medical treatment. A total of 34% of single vehicle casualties were attributed to drivers in the 17-24 year age group. This age group also represented a total of 21% in multi-vehicle casualties for the same time period.

Objectives

The goal of the booklet is to reduce the fatality and injury rate of novice drivers across the Moreton Bay Region by providing a practical educational tool based on best practice guidelines and to raise awareness of the importance of on road driving skills to develop safer driving habits. Specifically, the objectives included providing a practical tool for learner drivers, supervisors and community organisations to utilise in planning formal drives in the Moreton Bay Region; to increase the opportunity for learner drivers to experience a wide range of driving conditions and develop safer driving habits; to provide learner drivers the opportunity to plan drives with the view to accrued driving time toward the minimum 100 hour requirement of on road driving experience in the learner phase of the GLS; and to deliver a key action within the Moreton Bay Regional Council *'Road Safety and Strategic Action Plan 2010-2014'*. Specifically Action no: 9.1.3 'Develop and produce a 'Drives for Learners' booklet as a practical tool for supervisors and learner drivers in planning a variety of drives to gain driver experience'.

Method

A booklet containing current road safety content consistent with core state government road safety messages, current road rules legislation and a total of 13 drives encompassing the Moreton Bay Region was developed for distribution.

Working in partnership with TMR and QPS provided opportunities to utilise TMR driving examiners and police officers to drive and test the routes contained in the booklet. These agencies enhanced the booklet by offering knowledge and expertise in their particular field.

The evaluation component of the booklet included quantitative data collection. This involved the distribution levels of the booklet and the number of locations throughout the region. A voluntary questionnaire was also developed to provide feedback on the relevance, usefulness and usability of the booklet.

Results

Seed funding for the booklet was provided through the TMR ‘Community Road Safety Grants’ to develop the ‘Drives for Learners in the Moreton Bay Region’ practical booklet including the content, graphic design and initial print run utilising the original booklet idea from the Macarthur region in NSW. Content of the booklet was consistent with core state government road safety messages and current road rules legislation.

Reviewing the Macarthur booklet identified the opportunity to expand not only on the content, map and route delivery, but to include practical considerations including making the booklet larger in size (A4) and the role that colours play in relation to colour blindness and reader ability.

As part of the development of the booklet it became apparent that there was a need to provide etiquette and awareness tips – this resulted in creating the ‘handy tips’ throughout the booklet. For example, ‘always indicate left to exit a roundabout’ and ‘stay wide of the rider – a minimum 1 metre gap when passing a cyclist in a 60km/h or less speed zone’.

The project team recognised the opportunity to source learner drivers from the region for the 'photo shoot' and these images have been used throughout the booklet. Utilising ‘real life’ images of learner drivers added to the authenticity of the booklet along with ongoing community recognition of the learner drivers.

The ‘Drives for Learners in Moreton Bay Region’ booklet was launched mid-December 2014. Interest in the booklet is increasing throughout the region with more than 8,000 booklets currently distributed. Data from TMR indicates there are approximately 30,000 licenced learner drivers in the region. A web friendly pdf version of the booklet can be accessed on line through the Council's website https://www.moretonbay.qld.gov.au/roadsafety/

Process evaluation includes distribution of the booklet to a range of government and non-government organisations incorporating community centres, council offices/libraries, TMR customer service centres, high schools, local youth organisations and driving schools throughout the region. Promotion and distribution also occurs at events across the region, for example, more than 300 booklets were distributed at the 2015 Fatality Free Friday and Farm Fantastic events and it is envisaged this number will grow with future planned events.

Impact evaluation is also undertaken with a voluntary survey. The survey has a few short questions seeking feedback on relevance, usefulness and usability of the booklet. Due to the voluntary nature of completion to date results from the survey have been sporadic, however, anecdotal verbal evidence from driving schools, customer service centres and the community is that the booklet is a great resource and highly appreciated in the community. Promotion of the feedback survey is now enhanced with a survey notice insert to the booklet.

Discussion

The more opportunities learner drivers have to drive on different road types and conditions during the learner driving phase increases their depth of driving experience and capabilities to draw upon when they are driving solo.

The aim of the booklet is to provide a practical educational tool that is easy to use and raises the awareness and importance of on road driving skills to develop long term safer driving habits.

This booklet provides the learner driver and supervisor with a hands-on approach with the comprehensive maps and instructions and offers them a wider range of driving experiences.

The ultimate outcome for this booklet is working to decrease the fatality and injury rate of novice drivers across the Moreton Bay Region.

The next phase of the Learn, Drive Survive project includes developing workshop information and presentations for supervisors. This will provide supervisors with the tools to coach their learner drivers on how to be safer drivers.

Use of personal mobility devices for first-and-last mile travel: The Macquarie-Ryde trial

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Abstract

Electric-motored personal mobility devices (PMDs) are appearing on Australian roads. While legal to import and own, their use is typically illegal for adult riders within the road transport system. However, these devices could provide an answer to traffic congestion by getting people out of cars for short trips ("first-and-last mile" travel). City of Ryde council, Macquarie University, and Transport for NSW examined PMD use within the road transport system. Stage 1 of the project examined PMD use within a controlled pedestrian environment on the Macquarie University campus. Three PMD categories were used: one-wheelers (an electric unicycle, the Solowheel); two-wheelers (an electric scooter, the Egret); and three-wheelers (the Qugo). The two-wheeled PMD was most effective in terms of flexibility. In contrast, the three-wheeled PMD was most effective in terms of speed. One-wheeled PMD riders were very satisfied with their device, especially at speed, but significant training and practice was required. Two-wheeled PMD riders had less difficulty navigating through pedestrian precincts and favoured the manoeuvrability of the device as the relative narrowness of the two-wheeled PMD made it easier to use on a diversity of path widths. The usability of all PMDs was compromised by the weight of the devices, difficulties in ascending steeper gradients, portability, and parking. This was a limited trial, with a small number of participants and within a unique environment. However, agreement has been reached for a Stage 2 extension into the Macquarie Park business precinct for further real-world trials within a fully functional road transport system.

Introduction

New alternative vehicles such as motorised mobility devices (MMDs) and personal mobility devices (PMDs) are rapidly entering the Australian road transport system and are becoming common features of Australian roads and footpaths. Their entry marks both a migration from in-home assistive technologies (MMDs), as well as opportunities offered by new materials and propulsive systems that have seen the morphing of existing vehicle types such as bicycles and toy vehicles into electric-powered devices (PMDs) [1]. MMDs were developed for mobility assistance within the home or a building as a motorised wheelchair, but have migrated into the road transport system and morphed into an alternative electric vehicle. PMDs were developed as mobility alternatives to other forms of transport (cars, motorcycles, bicycles, pedestrians) within the road transport system with the aim of enabling sustainable transportation including accessible links with public transport [2].

Rose and Richardson [3] have noted that:

> "The motor car continues to evolve but it is being complemented by alternative means of independent motorised mobility including personal mobility devices, low powered two wheel vehicles and small footprint four wheel vehicles. For road network managers, the growth of alternative vehicles can have a variety of impacts and implications, from the design of individual elements of the road system, such as parking bays, to the refinement of the regulatory structures that govern vehicle use." (p.1)

That sustainable transport futures will require significant reductions in use of the private car is uncontested. Whether and how existing patterns and volumes of personal mobility can be sustained through other modes is far more controversial, especially in light of strongly-held preferences for the independence afforded by the car [4]. Technological solutions to this dilemma are frequently proposed. Electric and hybrid vehicles, for example, are being explored as low emission means of getting around that work with, rather than against, the cultural, social and habitual appeal of the car [5,6,7]. Attention has also turned to electric bikes, and in particular their potential to offset some of the fitness and distance constraints of conventional bicycles [8]. Car and other vehicle manufacturers are also developing and marketing technologies to provide an alternative to the car, especially for shorter trips and to be used on footpaths as well as roads. The Segway is the most commonly used and known of such devices (see review in [9], but they also include a plethora of two and three wheeled 'scooters', known by the shorthand terms 'low speed private transport mode' [10] or 'low speed mobility devices' [11], or, as in this paper, 'personal mobility devices' (PMDs, [2, 3]. Such technologies, like electric bikes, allow an individual rider to travel short distances quickly without the physical effort required of cycling, and in some their small size makes transfers between transport modes possible. They therefore, in principle, have considerable potential as sustainable transportation alternatives [12].

This sustainability potential of PMDs is currently curtailed by the safety and regulatory aspects of PMDs. In many jurisdictions across the world it is not legal to ride PMDs on roads or on the footpath, with limited exceptions [2,13]. The speed of PMDs, and their interaction with both pedestrians and with other vehicles, are areas of concern [1]. Safety concerns, especially around the impact of the speed and weight of such devices on collisions with pedestrians, are regularly raised [14]. There are also concerns about the use of such devices upon urban pedestrian infrastructure designed for walking.

Research on PMDs has been sparse despite being raised as a sustainable transport alterative more than ten years ago [12]. There is, however, a growing body of scholarship focused on PMDs that emanates from perspectives ranging across psychology, engineering, road safety, urban planning and transport policy. These studies have myriad foci, including: the performance and characteristics of PMDs [9, 15], their safety dimensions [16,17], acceptability as a transport mode [18], regulatory impacts [15] and use in real world settings [19]. Three themes are especially pertinent to their sustainable transport potential.

A first theme is an explicit evaluation of PMDs as a sustainable transport solution. In this theme, the potential of small, powered, devices to bridge the 'first and last mile' – between home and transit and/or transit and work locations – is considered. San Francisco's 'EasyConnect' project assessed the perceptions and feasibility of low-speed modes (specifically the Segway) in facilitating movement around transit hubs, and found that users willingly adopted the Segway as a means of getting around during the work day (e.g. going out to lunch) but were more likely to use electric bicycles to bridge the first and last mile [12, 19]. More recently, Iryo and colleagues [20] have suggested that low speed modes enlarge people's final destinations around train stations and other transport hubs, and it car trips to and from transit trips were switched to PMDs then there will be reduced transport emissions from these trips [see also 10].

A second theme is the safety dimensions of PMDs. There is a voluminous literature on the risk of injury to both riders and pedestrians, especially of the Segway [21], but a safety dimension more relevant to sustainable transportation is the contours of PMD use on existing infrastructure [17,22]. Here, the question is how, if at all, can such devices be appropriately used in pedestrian environments such as footpaths, shared paths and separated cycleway. There is even more limited research here, though the broader literature on pedestrian-cyclist interactions provides some guidance. Recent empirical studies from Australia and the United Kingdom found that cyclists moderate their behaviour (especially speed and direction) in the presence of pedestrians, and that there is little conflict between pedestrians and cyclists [23,24]. PMDs are different to bicycles in their potential speed and novelty to pedestrians, thus it is necessary to conduct specific research on their use in pedestrian environments.

A final theme in existing PMD research is the usability and acceptability of the devices. Mirroring research on electric bicycles, a Japanese study found a low level of recognition of PMDs among the general public and that acceptance increased after use [25]. However, this research was based on only 10 minutes of riding a PMD. To better understand acceptability it is necessary to undertake a more comprehensive analysis in terms of both extent of PMD use and evaluation of acceptability.

Given these potentials and policy concerns, it is surprising that such devices have largely been ignored by scholars interested in sustainable transport and in road safety. Moreover, the little research that exists focuses on just one device – the Segway – that is unique in terms of weight, speed and requisite rider skill, and that is qualitatively different from the proliferation of motorised devices appearing in cities around the world [12,13,14,18,20]. This paper addresses these research and policy lacunae, reporting on a study that explored the operation of PMDs in a naturalistic setting. The paper begins with an overview of existing research on PMDs and identifies key factors to be understood if they are to be successfully implemented as sustainable transport solutions. The bulk of the paper evaluates the viability of PMDs in pedestrian environments, focusing on user experiences and perceptions, as well as interactions with pedestrians. The project tested PMDs in an authentic setting, with a focus on their acceptability and perception to those riding them (‘riders’), and their interactions with pedestrians.

Materials and Methods

For the purposes of the present article, a shortened method section will be presented. For more details regarding the device selection and the criteria used in assessing safety and user acceptability see the report of the pilot trial of personal mobility devices at Macquarie University prepared for the PMD Project Steering Committee [26].

Building on the methodological foundations of three separate research trials conducted in Canada, Germany and the United States [14,16,19], the authors conducted a naturalistic study of participants riding PMDs on footpaths and shared paths on a university campus. As it is currently not legal to ride a PMD on a road or footpath in New South Wales, insurance and regulatory concerns limited participants to university employees, and bounded PMD use to within the university campus. Nonetheless, where, how often and how far each rider travelled on a PMD was determined by the rider, not the research team. The university campus has an area of 126 hectares, with capacity for individual trips greater than five kilometres. This was adjudged to be of sufficient size to gauge perceptions of use, and the density of pedestrians (a daytime campus population of approximately 20,000) sufficient to evaluate interaction

Devices

Two different devices were used in the study, selected according to a set of criteria focused on the safety for riders and others users of the shared use paths (see Table 1). Weight criteria were established based on analysing the potential risk of injury to the riders and other path users, which was directly related to the kinetic energy, but also the potential risk of back injury if the rider was to lift or carry the device. Width was determined to be not greater than the width of a standard wheelchair. A two-wheeled device and a three-wheeled (the latter gyro stabilized) device were chosen, as depicted in Figure 1 below. The particular models chosen were those that were in commercial (not prototype) production and available to be imported to Australia. Commercial prices were paid for each device and the research was not sponsored by the suppliers or manufacturers of devices. The power output of each device was limited, enabling a maximum speed of 10 km/h as measured on level ground with a 80 kg loading mass. GPS units were wired to the PMD's battery and the units turned on and off by the same switch or key as the PMD activation circuit. The GPD units tracked the speed of trips, distance travelled, and the time and location of the PMD within the university campus.

Table 1:

Specification	Two-wheeled personal mobility device	Three-wheeled personal mobility device
Designed maximum speed (km/h)	6/ 12/ 20/ 35 km/h	25 km/h
Motor Output (W)	250 W	1000 W
Weight (with battery)	15 kg	33 kg
Maximum load (kg)	100 kg	120 kg
Width (mm)	560 mm	580 mm
Brake System	Motor-brake	3 disc brakes
Foldable version	Yes	handle bar only

Figure 1: The two-wheeled PMD (left) and the three-wheeled PMD (right). From the authors.

Participants

Riders were recruited as volunteers from among university staff, via advertisements and other campus coverage of the trial, with a preference for those staff who travelled across campus on a daily basis. Seventeen riders in total (nine men and eight women) were recruited. They underwent training on the device, including information on the trial protocols regarding compulsory helmet use and the requirements to give way to all pedestrians, and to dismount when crossing roadways. Participants then rode a PMD for one week in pedestrian zones, principally footpaths. After one week, most participants were trained on another device and trialled that one for a week. Riders had an average age of 37 years; three quarters had full drivers' licences and 70 percent came to work as either a car passenger or driver. Forty percent used a bicycle on a regular basis.

Data collection and analysis

User experiences and perceptions were gained from *pre-, mid- and post-trial questionnaires* that were administered to gain subjective reflections of participants' experiences of riding different PMDs (see Table 2). Questions covered perceptions of ease of use, weight and storage. Answers were coded and simple descriptive statistics calculated. The sample size was not large enough for further statistical analysis. Riders were encouraged to write about their experiences on a Wiki site open only to university staff and students. At the end of the trial these blog posts were collated and thematically coded in terms of: pedestrian interactions, safety, fun, attracting attention, hills and stairs, infrastructure, incidents, lack of power, secure parking, technical issues, time saved and the weight of devices.

Table 2: Research questions examined, methods of data collection, and methods of analysis

Research question	Data collection method	Method of analysis
User experiences and perceptions	User questionnaire Qualitative comments	Descriptive statistics Thematic coding
Device usage	GPS tracking of speed and distance	Mapping of trip routes Average speed
Pedestrian interactions	2 fixed and 1 mobile surveillance camera	

Device usage was traced through GPS tracking which supplied the start date, time and location and each update the unit made including speed, location and distance travelled (Table 2). Data were updated at intervals of one minute. Camera locations were entered into the software.

Information on interactions with pedestrians was gained through rider questionnaires, as well as through fixed surveillance cameras placed at two sites of high pedestrian activity supplemented by a mobile camera places at two different sites at different parts of the trial (Table 2). These sites were chosen on the basis of where the PMDs were being ridden. When a PMD passed in the vicinity of a camera an alert was sent to the PMD email address, logging time, place and device. Data related to PMD events captured on the CCTV cameras were extracted from the footage using the time and date stamping. One hundred and thirty video events were extracted and analysed. Video events were analysed using a coding scheme designed to capture pedestrian interactions with PMDs, identify PMD riders' level of compliance and observe the riders' experiences to complement the questionnaires. Each clip was numerically coded for: time and date; location; device type; number of pedestrians present that either interacted or were in close enough proximity to a PMD to potentially interact with the PMD; number of vehicles present including motor vehicles, bicycles and skateboards; whether the PMD rider or pedestrians had to move out of the way; whether pedestrians were using technologies such as mobile phones or music through headphones that could distract them; and whether any incidents were captured. Each of the 130 clips underwent analysis based on the above coding scheme. After the initial analysis, a second analysis based on the same coding was conducted by a second person to verify initial analysis results and maintain reliability, validity and accuracy. A summary of descriptive measures such as frequency counts was produced from the data contained in all 130 cases.

Results and Discussion

Summary of PMD usage

Because PMD use was confined to the university campus during the workday, total usage of the devices is not directly relevant to their potential in sustainable transport terms. Nonetheless, an overview of device usage provides important background to user perceptions and pedestrian interactions. The actual usage of PMDs varied from participant to participant, ranging from 1.5 km to 30 km in one week. The average distance travelled in each day of use was more than two kilometres for both devices, with 50 percent of trips covering distances between 500 metres and 1000 metres, and 25 percent of trips extending to more than 1000 metres. The average speed per trip was 6 kilometres per hour, which is a little over a fast walking pace [1].

Perceptions of riders using a PMD

Before the trial, only a small number of riders had heard of PMDs and none had ridden one. Nonetheless, all riders of the two-wheeled devices found them easy to use, while 16 percent of three-wheeled device riders found it hard to use, principally because of difficulties with balance. All stated the devices became easier to use with practice. Riders identified the advantages of the PMD compared to walking to primarily be about speed, rather than expending less energy. Ninety percent of riders found using a device very or moderately enjoyable, and the same percentage found it moderately or very comfortable to ride (see Table 3). Three-wheeled devices were more comfortable but less enjoyable than two-wheeled devices.

Table 3: Level of enjoyment and comfort experienced

	Two-wheeled device (%)	three-wheeled device (%)	All (%)
Very Enjoyable	53.3	33.3	44.4
Moderately Enjoyable	46.7	41.7	44.4
Not Enjoyable	0	25.0	11.1
Very Comfortable	26.7	58.3	40.7
Moderately Comfortable	73.3	33.3	55.6
Not Comfortable	6.7	8.3	7.4

Likewise, qualitative comments from the blog emphasised the fun experienced by some riders: PMDs were seen as a more enjoyable way of getting around campus.

- *Having fun on the two-wheeled device (it brings back loads of happy childhood memories of riding around on a scooter).*

There were, however, a number of identified problems with riding a PMD on campus. Riders were asked to identify disadvantages, summarised in the table below and addressed in turn. Essentially, ease of use was compromised by perceptions of limited power, device weight, storage and portability, stairs and infrastructure (Table 4).

Table 4: Identified disadvantages of PMD use

	Two-wheeled device (% of riders identifying)	Three-wheeled device (% of riders identifying)	All (% of riders identifying)
Underpowered	46.7	25.0	37
Heavy	20.0	50	33.3
Too wide	0	41.7	18.5
Secure parking	20.0	33.3	25.9
Stairs	20.0	16.7	18.5
Infrastructure	13.3	25.0	18.5
Pedestrians	6.7	0	3.7

The devices were limited to 10 kilometres per hour through a limitation on power. A consequence of this was that devices struggled going uphill, or had to be pushed, and a widespread perception by riders that they were 'underpowered'. Almost 50% of two-wheeled device riders identified hills and being underpowered as the most common problem with their use of the PMD on campus.

- *The two-wheeled device is a slug up hill , on the flat it maintains its 10kp/h , downhill it accelerates beyond the 10 kp/h and you have to brake heavily . Big downside is uphill it's got nothing, having more acceleration would help this immensely.*

The video analysis showed that in eight instances the participant was walking the PMD (mainly two-wheeled devices) and on five occasions two-wheeled device riders used their foot to either support their balance or to add leg power to the device to go up a pedestrian ramp designed for wheelchair access.

PMDs are intended as portable devices, and riders were provided with quality bike locks to secure the devices to bike racks. However, most preferred to take (wheel, rather than ride) the PMDs into buildings, offices, meeting rooms etc. On the university campus this often meant negotiating stairs at some point, and difficulties with stairs and carrying PMDs were often identified disadvantages of the PMD.

- *After using the two-wheeled device for the week, I found it good to get across campus quickly, but overall it was more trouble than its worth in many cases. The size and weight of it make it bad for anywhere that requires it to be carried. If it were smaller and lighter, or if it collapsed to a smaller size this may be different.*

Weight is a key component of perceptions of portability. At 15 kg, two-wheeled device riders also identified its weight distribution and ease of folding as important and difficult, and half of three-wheeled device riders identified its weight of 33 kg as a disadvantage. Storage and secure parking at diverse locations was also an issue; a device is not really portable if there is nowhere to store it at a destination.

The project design anticipated that road and path infrastructure, as well as connections between the two (kerb ramps, crossings, etc.) would be a determinant of ease of use. An initial infrastructure assessment was undertaken by property staff at the university and minor changes made. Despite this, changes in surface, uneven surfaces and the increased elevation (or “bump”) often associated with kerb ramps were identified as issues. ‘Bumpy’ rides induced by certain types of paving across campus were not appreciated, for example:

- *It does not ride well over rougher terrain (eg, car park, cobbled areas) and can give your back a jarring, especially if you are an 'older' person (two-wheeled device rider).*

As a result of these difficulties, half of the riders (52 percent) used the PMD less than they had anticipated. The differences between the devices were stark here: two-thirds of three-wheeled device riders used the device less than anticipated, compared with 40% of two-wheeled device riders. The reasons for this reduction in use are shown in Table 5 below. Most notably, finding the device hard to use was not an issue for two-wheeled device riders, but was the third most important reason for using the three-wheeled device less than anticipated.

Table 5: Riders’ reasons for using the PMD less than anticipated

	Two-wheeled device (% of reasons identified)	Three-wheeled device (% of reasons identified)	All (% of reasons identified)*
Walking was quicker	12.5	7.7	9.5
Walking was more convenient	37.5	7.7	19.0
PMD was too heavy	12.5	30.8	23.8
Problems with secure parking	25.0	23.1	23.8
Needed exercise from walking	0	7.7	4.8
Helmet use was annoying	12.5	7.7	9.5
PMD was hard to use	0	15.4	9.5

Pedestrian-PMD Interactions

PMD rider experiences with pedestrians were largely positive, with one third of riders never experiencing difficulties with pedestrians, and sixty percent only occasionally experiencing difficulties. Indeed, for almost all riders, interacting with others on shared paths was considered easy. This was more so for two-wheeled device than three-wheeled device riders (see Table 6 below). A certain level of frustration with sharing was evident with the three-wheeled device, presumably because of its larger size and weight.

Table 6: Riders’ perceptions of interactions with pedestrians

	Two-wheeled device (%)	Three-wheeled device (%)	All (%)
Easy	92.3	50	86.7
Difficult	0	0	0
Frustrating	7.7	50	13.3

Riders' blog comments such as those below confirm these findings:

- *Pedestrians seem to be reasonably comfortable with two-wheeled device around. When they hear the sound of the bell/engine, they move to one side.*
- *I do reasonably well at weaving through pedestrians (two-wheeled device Rider).*

Several comments were made in regards to the devices attracting positive attention and three-wheeled device riders commented that pedestrians were more aware of its presence than the two-wheeled device, facilitating the ease of pedestrians moving out of the way.

- *There has been far more pedestrian/staff interaction with this device, but still, I've found it generally positive ...The sound of it coming definitely helps with people being aware of it too (three-wheeled device rider).*

When asked to identify common problems experienced riding on campus, the most frequently identified problem was pedestrians (25 percent of problems identified). When asked to expand, problems included navigating around pedestrians when the path was crowded and pedestrians being unaware, unresponsive or distracted, as evident in the blog comments below.

- *Pedestrians are even more unpredictable than I expected - stopping suddenly, ignoring bells, etc (two-wheeled device Rider).*
- *I had one pedestrian texting on the phone that walked straight into me. I had slowed in general anticipation and eventually came to an abrupt halt ... it's still hard to look into the faces to read expressions while also riding and anticipating walkers (two-wheeled device Rider).*

There was also one incident reported on a three-wheeled device due to the rider's attempt to give way to pedestrians on a narrow path. The rider lost balance when applying the brakes, ran a couple of steps then fell on the road resulting in minor scrapes and bruises.

Objective information from the video confirmed these subjective impressions (see Table 7). Of the 130 instances of PMD use captured on video, pedestrians were present on 104 occasions (87%). Overall, there was harmony between PMD riders and pedestrians as they passed each other. The majority (79%) of the time PMDs did not have to alter their direction, slow down or brake for pedestrians. Neither did pedestrians need to move out of the way (90% of the time). Even during times of significant crowding of 10-15 people in the proximity of a PMD, both the PMD and pedestrians appeared to seamlessly anticipate and navigate around each other. On five occasions the rider was observed to disembark in order to be cautious of oncoming pedestrians. The instances where pedestrians had to move out of the way were highest for the three-wheeled device (15%).

Table 7: PMD-Pedestrian Interactions

	Two-wheeled device (n=71)	Three-wheeled device (n=48)	All (n=119)
Pedestrians present	63	41	104
PMD rider changed course	15	7	22
Pedestrian(s) changed course	3	4	7
Both pedestrian and PMD rider changed course	2	3	5

Neither PMD nor pedestrian rider changed course	43	27	70

Concluding comments

PMDs are certainly a novel (and sometimes fun) form of transport has found that in specific environments users adopt small motorised devices as a means of getting to destinations more quickly than walking. This study, though small and exploratory in nature, has found that the barriers to the uptake of PMDs as a sustainable transport option are far from insurmountable. With controlled use in a real world setting, PMDs are perceived to be easy to use and valued for their ability to deliver people to destinations more quickly than walking. This study hence provides important lessons for policy makers concerned with the appropriate regulations and infrastructures for the general class of small, motorised devices. Principal here is minimizing weight given existing road and path infrastructure will almost certainly necessitate carrying or lifting the device at some stage. Another important consideration is ensuring that PMDs have adequate power to ascending ramps and other inclines, while limiting their speed. PMD users should not expect, or be permitted, to travel at speeds much greater that those of pedestrians. This means a maximum speed on open footpaths of 10 km/h, and a maximum speed of 5 km/h for areas where pedestrians are present (and 3 or 4 km/h is preferable as a 'tortoise mode' speed in busy areas of pedestrian movement) [1].

The design of the PMDs is an issue, as there is concern that human factors not fully taken into account with these devices (e.g., the weight and associated portability of the devices, as well as the width of foot plates, small diameter and narrow wheels, lack of a speedometer, lack of speed limiting, lack of storage provision and access to battery charging). Overall, the usability of all PMDs is compromised by the weight of the devices, their portability (particularly when used in conjunction with public transport), provision for parking and storage, and difficulties in performance with hill climbs and descents. That said, while PMD use is illegal for road use in Australia currently, these devices are largely compatible with existing road and pedestrian infrastructure (especially for the lighter and narrower devices).

Legal restrictions prevented the research from assessing PMD ability to bridge first and last mile distances. Nonetheless, the project tested PMDs in an authentic setting, with a focus on their acceptability and perception to those riding them (‘riders’), and their interactions with pedestrians. Subsequently, agreement has been reached for a Stage 2 extension into the Macquarie Park business precinct for further real-world trials within a fully functional road transport system. Lightweight, two-wheeled scooters are most appropriate from the perspective of riders, pedestrians and sustainable transport, and their functional use in bridging first and last mile distances will be an important consideration.

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Safety culture and speeding in the Australian heavy vehicle industry

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Abstract

Inappropriate speed and speeding are among the highest causes of crashes in the heavy vehicle industry. Truck drivers are subjected to a broad range of influences on their behaviour including industrial pressures, company monitoring and police enforcement. Further, drivers have a high level of autonomy over their own behaviour. As such it is important to understand how these external influences interact with commonly shared beliefs, attitudes and values of heavy vehicle drivers to influence their behaviour. The present study uses a re-conceptualisation of safety culture to explore the behaviours of driving at an inappropriate speed and speeding in the heavy vehicle industry. A series of case studies, consisting of interviews and ride-along observations, were conducted with three transport organisations to explore the effect of culture on safety in the heavy vehicle industry. Results relevant to inappropriate speed are reported and discussed. It was found that organisational management through monitoring, enforcement and payment, police enforcement, customer standards and vehicle design factors could all reduce the likelihood of driving at inappropriate speeds under some circumstances. However, due to weaknesses in the ability to accurately monitor appropriate speed, this behaviour was primarily influenced by cultural beliefs, attitudes and values. Truck drivers had a tendency to view speeding as relatively safe, had a desire to speed to save time and increase personal income, and thus often attempted to speed without detection. When drivers saw speeding as dangerous, however, they were more likely to drive safely. Implications for intervention are discussed.

Introduction

Inappropriate speed and speeding are among the highest causes of crashes in the heavy vehicle industry. Driving above the posted speed limit and/or too fast for the conditions is a well-known risk factor for traffic incidents. Driscoll (2013) reported on 461 major heavy vehicle crashes in 2011, stating that inappropriate speed was responsible for 25.4% of these crashes. This figure was reportedly lower than in previous years. Chen and Chen (2011) examined 10 years of crash data from Illinois, USA, finding that speed influences the severity of outcomes in single-vehicle truck crashes, yet not multiple vehicle crashes (lack of an increase in severity in multi-vehicle crashes may be associated with the likely severity of a light vehicle crashing with a heavy vehicle, regardless of speed, due to the size and mass of the truck). Finally, Brodie, Lyndal and Elias (2009) analysed coroners' reports, finding that excessive and/or inappropriate speed was involved in 43.1% of fatalities in which speed was documented.

A number of researchers have indicated that safety culture could provide a useful avenue for improving safety in the heavy vehicle industry (Gander et al., 2011; McCorry & Murray, 1993; Short, Boyle, Shackelford, Inderbitzen, & Bergoffen, 2007). Safety culture has seen significant attention within the literature in recent years, and there is significant debate about the nature of safety culture and how it can be defined (see reviews by Choudhry, Fang, & Mohamed, 2007; Edwards, Davey, & Armstrong, 2013; Guldenmund, 2000). There are two major approaches to safety culture in the literature. One views safety culture primarily in terms of organisational structures and systems, and has been called a normative or functionalist approach (Edwards et al., 2013; Nævestad, 2009). The other views safety culture primarily in terms of shared beliefs, attitudes and values, and is referred to as an anthropological or interpretive approach (Edwards et al., 2013; Nævestad, 2009).

In a previously published review, the authors examined journal articles about heavy vehicle driver health and safety identifying a broad range of influences on health and safety in heavy vehicle industries (Edwards, Davey, & Armstrong, 2014). These included government regulations and enforcement, organisational factors, customer pressures and requirements and road/environmental factors. In addition to these external factors, it should be noted that heavy vehicle drivers have a high level of autonomy over their own behaviour (Arboleda, Morrow, Crum, & Shelley Ii, 2003). Further, Sully (2001) suggested that due to the amount of time heavy vehicle drivers spend away from their depot means that they are more likely to associate themselves with an industry wide road culture than to a specific transport company. Thus, to understand speeding in the heavy vehicle industry, there is a need to explore both external and internal influences on speeding, and to look beyond the traditional boundaries of an organisation. This presents a barrier to the application of the two traditional approaches to safety culture, which typically focus on one of these aspects in isolation and within the confines of a single organisation. The authors previously presented an alternative approach to safety culture in which safety culture is viewed in terms of the combined impact of both external contextual elements and shared beliefs attitudes and values (Edwards et al., 2013). More importantly, this framework held that safety related behaviours were influenced by the interactions between cultural and contextual factors. To date there is no strong evidence to suggest that culture can be deliberately changed (Edwards et al., 2013; Nævestad, 2009), however, by understanding the existing culture and how it interacts with contextual factors, it may be possible to change these contextual factors to work with the culture of a workforce to improve safety (Edwards et al., 2013, 2015). The present study uses this framework of safety culture to explore the effect of culture on speeding in the heavy vehicle industry.

Method

A series of three qualitative case studies with transport organisations were conducted to investigate safety culture within the Australian heavy vehicle industry. These case studies formed a collective case study (Stake, 2005), in which the three organisations chosen for the research were selected to provide insight into the broader industry. The case studies were conducted using a combination of ethnographic methods (interviews and participant observations) and grounded theory analysis techniques (specifically those of Corbin & Strauss, 1990).

Participating Organisations

The three participating organisations (identified here as Company A, B & C), were selected on the basis of knowledge from a series of preliminary interviews. These interviews indicated that both safety and the culture in the industry differed depending on the location, type of vehicles used and goods transported, distance of the haul, and the size of the company. The three companies were selected to sample this diversity to enable similarities and differences to emerge. These differentiating characteristics for each company can be seen in table 1.

Table 1. Case study organisation characteristics

	Company A	**Company B**	**Company C**
Company Size	Medium (~50 trucks)	Medium (~50 trucks)	Small (<10 trucks)
Location Type	Capital city	Capital city	Regional centre
Major Freight Task	General goods	Specialised freight	Livestock
Typical Distance Carried	Medium-long (intra- and inter-state)	Local (plus some medium-long	Short-medium (within region)

Main truck types	Semi's and B-Doubles	Rigid, crane mounted, heavy haulage, long loads, semi's and B-doubles	Semi's, B-doubles and road trains

Company A is a medium-sized family-owned and operated transport company. The organisation employs approximately 100 staff and owns over 50 prime movers. Semi-structured interviews and observations were conducted with 10 staff members. Four managerial, administrative and operational staff (two managers, one health and safety officer and one operations manager), along with six heavy vehicle drivers, took part in interviews. Six observations were also conducted with heavy vehicle drivers.

Company B is a medium sized transport company, employing approximately 100 staff with over 50 trucks. Due to the diversity within Company B, the organisation has a number of managers overseeing branches within the company. Ten interviews were conducted within Company B. Participants consisted of the compliance officer, and part owner, of the company, two regional managers who each oversee approximately half of the fleet, five branch or depot managers, two driver trainers, and an operational manager. Eight observations were conducted, typically covering a driver's shift.

Company C is a small-sized transport company based in a regional centre. Family owned and operated, the organisation consists of six prime movers and various trailers, and employs between six and 10 people at any point in time. Five interviews were conducted with the owner/manager, compliance officer, two drivers, and the owner/driver/head-mechanic. Three observations were conducted.

Method

The interviews lasted between 30 minutes and two hours and covered a variety of topics. The first questions were typically aimed at eliciting information regarding the history of the individual and identifying major safety concerns in their work role. Later questions sought to identify contextual, cultural and behavioural factors which influence these safety concerns. Participants were asked about specific behaviours and outcomes which were not spontaneously discussed. Prompts were seldom required as participants appeared eager to share their perspectives on safety.

Typically conducted after the interviews, observations of drivers occurred during drivers' usual shifts. Most observations lasted the duration of the shift, although some lasted for a portion of the shift (range of durations was 4-15 hours, with the exception of two which occurred to take the researcher to another depot). During observations the researcher conducted informal interviews similar in nature to the staff member interviews. Additionally, questions were asked which specifically related to tasks witnessed.

Results and Discussion

Throughout the case studies a significant degree of congruence was found across members of the three companies. As the case study companies were selected to provide a broad overview of perceptions within the industry from differing subsections, this congruence allowed the case studies to be interpreted collectively as originally intended. This gives support to the notion of an industry wide culture, and for the purpose of this paper, differences between companies will be noted where relevant however, the majority of discussion will incorporate responses from members of each company to shift focus away from specific companies and toward a broader industry focus. It should be noted that during observations and interviews with drivers only hand written notes were taken, reducing the possible length of quotes. Conversely, during interview that occurred with staff members, audio recordings were made. As such, the majority of large quotes are from managers. Nonetheless, the quality of hand-written notes permitted analysis to be conducted both on verbatim quotes from audio recordings and the detailed written notes. As such, while the majority of reported quotes are from managers, the analysis allowed equal voice to drivers and staff members.

Participants generally acknowledged speeding to encompass both driving at an unsafe speed for the conditions and exceeding the posted speed limit. Heavy vehicles are legally required to be speed limited to prevent speeds exceeding 100km/h. As such, this limiting technology only reduces speeding on highways with a posted speed limit of 100km/h or greater. Thus, it was concerning that many participants tended to define speeding as exceeding 100km/h. When asked about speeding one Company B driver stated, due to the speed limiter, "I can't speed". Similarly, the driver/manager of Company C (both is the manager and drives a truck) said that their drivers "can't speed because they're limited". Given that heavy vehicles can easily exceed lower posted speed limits this perception is clearly flawed, but highlights that some participants thought speeding was not a possibility.

There were a broad range of factors suggested by participants to be associated with speeding behaviour and the likelihood of outcomes. These included both contextual and cultural factors. For the purpose of the present discussion contextual factors will be discussed in brief to leave room for greater discussion of cultural beliefs, attitudes and values.

Contextual factors influencing speeding

Many of the contextual factors identified by participants as being related to speeding and speed-related crashes were obvious or commonly known risk factors. These included factors such as inclement weather reducing the safe speed of travel, other vehicles and road works causing delays which lead to increased work pressures. Of particular importance however were the roles of law enforcement, organisations and customers.

Law enforcement and speeding

Traffic law enforcement is a cornerstone to road safety strategies worldwide. With regards to heavy vehicles and speeding there were three main methods of monitoring and enforcement. These were (1) speed limiters (on all heavy vehicles except those too old for the technology), (2) fixed camera enforcement (standard and point-to-point), and (3) mobile enforcement. Whilst each of these has some merit, there were weaknesses identified by participants which reduce their deterrent effect.

Speed limiters were seen as easy to tamper with for those who wish to do so. More importantly, however, in addition to the fact that speed limiters only set a maximum speed, which does not adapt to varying speed zones, it was noted that the mechanism by which speed limiters operate does not prevent speeding downhills.

> *The road speed is gutted at 100km/h. They will go faster than that off a hill because they're not gear-bound at 100km/h but I think they'll top out at just over 120 or something like that, 130.* (Company A Manager One)

Standard speed cameras were generally seen as ineffective as truck drivers become familiar with the roads they travel and know the exact locations of each camera they will pass. Thus, they only need to watch their speed in these places. Further, point-to-point speed cameras were seen as easy to overcome, as every truck driver is aware of the legal times and many will time their trip and wait before passing the next camera. Additionally, delays afford additional time for drivers allowing them to speed through lower speed limit sections without triggering fines.

SAFE-T Cams don't stop you from speeding. There are hills between the cams so you lose speed up the hills and can go like hell down them... Going through towns slows you down so you go like stink on the highway and at daytime you hit traffic lights which can add five minutes to your time. (Company A Driver Six)

Finally, while mobile enforcement has benefits, the use of UHF radios allows truck drivers to be aware of police locations at all times on the road. Overall, these issues mean that there is an absence of certainty of punishment for speeding, and thus a very limited level of deterrence. Thus, it is seen as unlucky to be caught for speeding.

I have had two speeding tickets from running off hills in the past seven months... just my bad luck that when I did it there was a cop down the bottom, plus I was on the wrong radio station so I didn't hear about them. (Company A Driver Six)

Transport organisations and speeding

The organisation's primary roles in speeding come from the method in which they pay drivers, and the approaches used to monitor and enforce speed adherence. Starting with the payment of drivers, hourly rates were associated with safer behaviour as driving slower results in greater income. Conversely, as stated by one Company B driver, payment by the kilometre or load is a "good incentive to drive fast", as travelling the same distance in less time is a more efficient way to earn money. Of the three participating companies, Company A paid a km rate for all long distance drivers, but an hourly rate for local drivers, Company B paid all their drivers an hourly rate, finally Company C drivers are paid a salary (which was comparable to a load rate due to the inability to earn overtime if the load takes too long).

Basically the drivers over at (previous employer location), they're getting paid a kilometre rate. So it's in their own interest to go like gun it all the time and they do gun it all the time... Over here they get paid on an hourly rate so they're not actually achieving anything by speeding and obviously our trucks are regulated to down to 95km and theirs are still 105, 110km. (Company B Branch Manager Two)

Each company relied on two primary means to monitor speed compliance – satellite tracking and speeding infringement notices from government departments. The satellite tracking methods of each company were capable of reporting current speeds and sending alerts to managers when vehicles exceed a chosen speed limit. Though they can be used to alert managers to different speeds in different locations, thus monitoring all speeding above the posted speed limit, they were typically only used to detect speeds in excess of the speed limiter. Company C managers did indicate that they will on occasions actively watch the tracking monitor and (from memory) determine whether the vehicle was speeding on a given road, however, this only occurred sporadically. Company B did implement specific speed zones in two locations, one of which was near a depot, and the other was on a specific road within a major city. These locations were monitored due to either past speeding fines or complaints by local residents regarding their trucks. As such, while there are cases of satellite tracking being used more thoroughly, satellite tracking was predominantly only used to detect speeding down hills, or speed limiters that have been subjected to tampering.

Tampering with speed limiters is easy, you just put a wire or a box over it but you can't do it without being caught. Satellite tracking shows vehicle over limited speed for an extended period of time and you know they have tampered. People are sacked immediately for it, has happened a few times. (Company A Driver Three)

Enforcement of speeding in each company was largely through non-conformance notices. For first offences and minor breaches, non-conformance notices were typically used to inform the driver that they were detected and to remind them to comply with the upper speed limit. Within Company A, one driver suggested that individual offences go unpunished, and that drivers will be reminded to slow down, yet that repeated offences are followed by non-conformance notifications, and/or one week without work and payment. However, one Company A driver stated that he "had this truck up to 120m/h downhill but it was never followed up".

> *...we normally ring up the driver and say: Oh what's the problem how come you put your foot down or what happened there? And we try and monitor that as well... Of course then we sort of have to say: Right, you know you're going to get chastised for it. You know you're not in deep shit just keep it down, keep your speed back like don't run it off the hills.* (Company A Operations staff Member)

Finally, infringement notices provided by police to the organisation gives additional monitoring. In the few cases where drivers trigger a point to point or fixed camera the infringement is sent to the company, who may then reprimand the driver as desired.

Customers and speeding

Whilst customer pressures may encourage speeding, it was generally stated that customers seek to ensure driver speed compliance due to their chain of responsibility requirements. This primarily occurred through auditing company records of traffic infringements and satellite tracking, and how the company manages these. However, it should be again stated that there are weaknesses in these methods of detecting speeding.

> *We're closely monitored ... there's a lot of trucks here that are painted (colour with customer name) on the side. We do a lot of work for them. We're very closely monitored and essentially they even do their own audit on us every six or 12 months... To make sure we're not breaking the law.* (Company A Manager One)

Contextual factors: Summary

From the above contextual factors it can be seen that there is a relative lack of successful monitoring and enforcement of speeding in the heavy vehicle industry. Police enforcement was only seen as effective in the immediate presence of fixed cameras or mobile enforcement (as drivers know their location), and had limited lasting influence on behaviour. Similarly, the three organisations only successfully monitor tampering with speed limiters or running of hills. Finally, while customers may require evidence of the management of speed, due to limitations in organisational monitoring, this is not sufficiently beneficial. On the other hand, payment methods used by the company can provide incentive to either speed or drive slower. Overall this means there is an absence of sufficient external motivation to adhere to speed limits, and in some cases there is incentive to speed.

The influence of culture on speeding

A number of the common beliefs, attitudes or values were identified throughout the case studies as having relevance to speeding. These broadly included seeing speeding as unintentional, viewing speed limiters as unfair, the value placed on time, and a collection of traits related to learning styles and the results these have on behaviour.

Speeding as unintentional

Generally speaking, there was a tendency to excuse speeding behaviour as merely unintentional. As stated by one manager from Company A, "everyone does it, it's not a purposeful thing". One health and safety officer, who previously worked in road design, even indicated that truck drivers may miss the posted speed limit and drive at the speed that 'feels' right for the road. This unintentional speeding was linked to the need for drivers to measure travel time between point to point cameras, even though this was also linked with deliberate punishment-avoidance strategies. Though it is clear that such behaviour can occur unintentionally, it is concerning that one of the major risk factors for crashes could be simply dismissed as unintended, and there is a need to address this issue. To prevent unintentional speeding, the use of GPS systems which inform drivers when they exceed the speed limit could be beneficial for the industry.

Speed limiting as unfair

Throughout the case studies it was evident that drivers also placed a high value on fairness, thus disliking rules or regulations that they thought were not fairly implemented. The requirement of trucks to be speed limited was often deemed unfair. While it was not suggested that cars be speed limited to the same speeds as trucks, it was argued that cars should not be designed to travel as fast as current designs permit. For this reason one Company B manager stated that truck drivers feel like 'sitting ducks'. That is, truck drivers felt that they were being unevenly regulated when compared to other vehicle drivers. This perception of unfair treatment has the potential to develop an 'us and them' mentality leading to feelings of hostility and resistance to regulations. Importantly, it should be noted that this feeling that the regulations are unfair does not mean that they disagree with the regulation, only its unfair application.

> *From the truck driver's perspective I guess he feels like a bit of a sitting duck. you know. It is hard to control but...governed, trucks are governed to 90, cars can do 220. Why do they need to do 200? Why on earth do we have a car that does 220km/h and gets sold to a 17-year-old on his birthday? There's nowhere in Australia you can do 220km/h, doesn't need to go that fast.* (Company B Branch Manager Four)

Value placed on time

Truck drivers commonly placed a high value on time. This has clear implications for speeding, as driving faster reduces travel time. As was discussed above, payment methods can provide an incentive for speeding. The effect of payment was seen to have a direct impact on driver's perceptions of the importance of time. In fact, drivers from company A (where local drivers are paid an hourly rate) commonly indicated that "on local time doesn't matter coz you're paid by the hour". However, non-financial motivations for saving time also had an influence on speeding. For example, one Company A driver stated that it is beneficial to reach a destination sooner in order to sleep before the sun rises. Point-to-point speed cameras that have short intervals (e.g. 30 minutes maximum between cameras, can reduce this effect, as speeding would result in regular stopping. Nonetheless, as drivers experience delays between many cameras, it was indicated that they speed to catch up on lost time. Further, it was highlighted that in order to make up for delays and save time, truck drivers may speed through lower speed limit zones.

> *So they get to an 80km/h zone or a 70 or a 60 and they just keep on going. They come into an 80km/h zone and say keep doing 100. And I'm sure you're guilty of doing it... you know you go down the road and it drops back to 80 for a section or whatever and you just keep it at whatever was the cruise control was set at. And it's the same as truck drivers that have been stuffed around for the last hour by someone so they just hold it flat through a village to make up that time.* (Company A Manager One)

Is speeding safe or dangerous?

It was evident that every truck driver who participated in the study placed a very high priority on safety. That is to say, when drivers felt that a particular course of action could lead to a crash or injuries for themselves or others, they would avoid the act. Conversely, they would always seek to conduct a behaviour they felt would improve safety. A large number of participants indicated that they perceived speeding to be a hazardous behaviour. As stated by the driver/manager of Company C "it's dangerous to speed, shit yeah". Similarly one Company C driver stated that another driver involved in a crash "was lucky he wasn't going faster". More generally, one Company A driver said "these things (trucks) are too dangerous (to speed) as far as I'm concerned". Conversely, a number of drivers did not hold these same views. For example, one Company A driver disregarded the effects of speed by suggesting that speed was irrelevant if someone cuts in front of you. As this driver believed that most incidents were caused by other vehicles, speeding was not considered dangerous, as the principle cause was not speeding, but the behaviour of others. The primary mechanism through which truck drivers determined what was safe and dangerous was their own experience and stories of other drivers. It was common throughout the observations for drivers to explain why they believed a specific action either increased or decreased safety from their own experiences as well as stories of other drivers. This may have a long historical basis in the industry as, in past years, truck drivers were often left with the sole responsibility of safety, while managers and organisations gave little priority to safety. While this has shifted, there is still a reliance on personal experience and being told stories by other drivers.

> *It wouldn't even be the last 20 years where there's been a big focus on safety and I'm not saying it's wrong, I totally agree with it. But before that, like when I was driving... your mate might come along to you and say oh just be careful tying that down it might slip and that sort of thing but there's no real focus on safety.* (Company B Region Manager Two)

'Normalisation of deviance' was a phrase first used to describe a process evident in the challenger space shuttle disaster. Vaughan (1996) argued that after successive disaster-free flights involving shuttles with the same flaws present in the Challenger shuttle, members of NASA began to believe the flaws were acceptable. This process of past experiences justifying unsafe acts was referred to as normalisation of deviance. In the case of the heavy vehicle industry, while crashes a far too common at an industry wide level, for the individual driver or company, crashes are a very rare event. Thus, the reliance on stories and experience creates a vulnerability to normalisation of deviance within the industry. One Company A manager stated that the organisation had experienced very few speed-related crashes, as they were mostly related to other causes, and this was immediately preceded with discussions regarding truck drivers choosing to speed through towns. The lack of experienced incidents that were attributed to speed led to a false confidence in the safety of speeding.

> *A lot of the highway is 100 but through the towns and that it is somewhat of an issue because blokes like to make up time so of course they speed through towns. We have very, very few speed-related crashes. They're normally road condition-related or stupidity-related or fatigue-related.* (Company A Manager One)

The same manager indicated that one driver from the company had previously spun a truck on a highway at high speeds in the wet, yet attributed this not to speed but to the stupidity of the driver. This view was mirrored in the perspectives given by many drivers regarding speed, and highlights how false causal attributions can shape beliefs regarding the dangers associated with speeding. It should be noted however, that due to the reliance on stories and personal experience, the use of stories also presents an avenue for effective training. Incident reports were used by company B in their training for a variety of safety behaviours (no specific examples of speeding were discussed by participants), and with these behaviours, there was seen to be a high level of compliance due to a belief that these behaviours were important to safety.

The results of seeing speeding as safe

Regarding government legislation and rules, a number of Company B drivers suggested that speed limit compliance held significant safety benefits. One driver in particular stated that “you do the speed limits for a reason, the signs are on the road for a reason, they’re there for safety”. This belief that the rules exist for safety extended to many drivers with a belief that speeding was dangerous. Unfortunately, however, many drivers did not hold positive views towards speeding regulations due to a belief that speeding is relatively safe. For these drivers, they would speed, if they could do so without being detected. That is, when a driver views speeding as relatively safe, their own speeding behaviour is predominantly modified by a desire to avoid punishment, either through avoiding detection, or where not possible, temporary compliance. Given the findings with relation to monitoring and enforcement, it can be expected that this means that these drivers have the ability to regularly speed in zones with a posted speed limit lower than the speed limiter installed in the vehicle, or when going down hills. This again highlights the need for drivers to believe that speeding is relevant to safety.

Conclusions

The case studies reported in this paper were conducted with three transport organisations taken from distinct sections of the industry, which according to industry members should have been quite different. The high level of congruence between each company given some support to Sully’s (2001) assertion that there may be a broad industry wide culture, pervading beyond the traditional organisational boundaries used in safety culture research. Nonetheless, it should be recognised that without further research confirming these findings apply more broadly throughout the industry, the results of this paper should be interpreted with caution and not generalised across an entire industry.

A broad range of cultural and contextual factors were identified which were relevant to speeding. Consistent with past research, there were influences from government departments, organisations and customers which had the ability to influence aspects of speeding (Edwards et al., 2014). Additionally there were a number of cultural beliefs, attitudes and values which were identified in the responses of participants. Whilst these included specific attitudes towards speed limiters and a view that speeding was at times unintentional, they also included the value placed on time and a series of beliefs and attitudes related to the value drivers place on safety and the tendency to learn primarily through experience and stories. In both of these later cases, it was evident that there were interactions between cultural and contextual factors which led to specific behavioural patterns, supporting the use of the current framework (Edwards et al., 2013).

It was evident that drivers placed a high value on time, and that this could lead to choosing to speed to save time, or make up for delays. Some of the reasons highlighted for this by participants could be seen a common for many light vehicle drivers, such as a desire to get home quickly, and some were specific to heavy vehicle driving, such as wanting to get to a safe rest location in time to sleep before the sun rises making sleep difficult. That unsafe behaviour can be associated with an attempt to make up lost time is not new, and was also notably demonstrated by Snyder (2012) in an ethnographic study of a driver driving through fatigue in order to make up for loading delays. Importantly, the current study demonstrated the relationship between payment models and speeding to make up time. Participants clearly stated that payment by the km or load (which is interchangeable as a given load has a predetermined location and thus distance to travel) is an incentive to speed in order to make the same amount of money in less time. Conversely, payment by the hour was seen to reduce the value placed on time, as delays and slower travel times actually increase the driver’s income for the same load. The relationship between payment and safety is also not new as such. The Australian Transport Workers’ Union (TWU) has long lobbied for ‘safe rates’. Of particular note, the TWU placed a submission to the Road Safety Remuneration Tribunal arguing that drivers are often not paid for waiting times, and feel pressured to speed (Transport Workers' Union, 2012). Past research has also supported the link between payment and safety.

Belzer, Rodriguez and Sedo (2002) found that within the USA heavy vehicle industry higher levels of payment were associated with lower crash rates. Further, Williamson (2007) found that Australian heavy vehicle drivers were more likely to use illegal stimulants if they were paid a distance rate, or were paid below the award rate. The current findings support the need for pay which doesn't provide an incentive to speed. The findings from this study add to the arguments that the TWU have offered, and show similar trends to that which Williamson revealed with stimulant use, indicating that regardless of the amount of pay received, payment per km will always give incentive to travel faster and avoid delays. Thus to limit the incentive to speed, it is recommended that distance and load based payment be eliminated in favour of an hourly payment.

The second series of interactions were based around the priority drivers give to safety and the tendency for drivers to learn what is safe through experience and stories. The findings highlighted that drivers can be vulnerable to normalisation of deviance (Vaughan, 1996), and when this occurs, resulting in drivers viewing speeding as safe, they will seek to avoid punishment through either driving at the legal speed limit when in the presence of police enforcement or speeding while avoiding detection. Existing monitoring techniques were found to be insufficient to regularly detect and deter speeding. While there is a need to improve these methods of monitoring, without passing legislation to download vehicle data, or force organisations to monitor speed in all zones, it may be difficult to truly ensure speeding doesn't go undetected or develop sufficient deterrence. However, as was briefly indicated, it may be possible to increase internal motivation to drive at a safe speed through the use of speed-related incident reports in training. There is a clear need to ensure drivers have a firm belief that speeding is dangerous.

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A typology of laws in Australia affecting the safety of bicycle users

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Abstract

Cycling is becoming increasing popular across Australia, both as a means of recreation and commuting (Australian Bicycle Council, 2013). Cycling interest groups as well as government agencies, such as the Western Australia Department of Transport, promote the use of bicycles as a healthy and more environmentally friendly alternative to motor vehicles (Western Australia Department of Transport, 2015). However, survey-based research suggests that safety concerns remain a major deterrent for adults choosing to cycling (Rissel & Campbell et al, 2002). Unfortunately, those concerns are justified. A 2014 study shows that the incidence of high threat to life crashes involving cyclists has increased by almost 150% since 1999 (Harrison, 2014). During that same time period the incidence of high threat to life crashes involving road users in protected vehicles has remained relatively constant. In NSW, from 2012 to 2014 motorist fatalities reached record lows, whilst contemporaneously cyclist fatalities doubled (NSW Centre for Road Safety, 2014). Despite this disparity, comparatively few public resources are dedicated to improving the safety of Australia's road environment for vulnerable road users, such as cyclists.

The law's role in improving cyclist safety

The role of legislation in improving cyclist safety is three-fold. Firstly, legislation can coerce road users to conduct themselves in furtherance of cyclist safety. For example, requiring cyclists to use lights and reflectors when riding at night might reduce the likelihood of collisions with motorists, who may otherwise not have seen the cyclist (Wood & Lacherez et al, 2009). Secondly, the creation of liability (civil and criminal) for potentially dangerous behaviour, such as speeding, can have a deterrent effect, which can increase the safety of road environments. Thirdly, legislative schemes can be used as tools to legitimise the co-sharing of road infrastructure by all vehicle types. The legitimising power of legislation is particularly important for bicycle users as Rissel et al (2007) suggest that popular negative perceptions of cyclists may contribute to aggressive and dangerous motorist behaviour. However, for road laws to have those desired effects, they must be carefully designed and sympathetic to the needs of all road users.

Aims

While legislative strategies are often seen as primary methods by which to promote the safety of vulnerable road users, there is little attention given to the way in which legislative schemes interact with each other, or even if the schemes are designed with vulnerable road users in mind. A first step towards removing that gap in the literature is to develop a typology of legislative schemes affecting bicycle riders in Australia. This paper develops such a typology, highlighting overlaps and inconsistencies between and within Australian jurisdictions.

The paper will thus provide a clear understanding of the extent to which legislative schemes need re-alignment before they can be validly seen as the legitimate foundation underlying road safety infrastructure and education for bicycle riders.

Methodology

Legislation pertaining to the use of roads and road-related areas in all Australian states and territories were catalogued. Inquiry was then narrowed to those legislative instruments that could materially affect cyclist safety. To ensure the validity of this analysis, only those legislative instruments that were patently immaterial to cyclist safety were not studied (e.g. *Road Transport (Vehicle Registration) Act 1999* (ACT)). A systematic review of relevant legislation was carried out to create a database of laws affecting cyclist safety, which included details of inter-jurisdictional similarities and differences.

The completed database was then interrogated in order to identify categories, which could be used to group the laws by type. Based on those groupings, a brief review of academic literature was conducted to contextualise some of the observed discrepancies between the legislative schemes in different states and territories. That review is presented at the end of this paper as an introduction for further research, which may use this typology as a foundation for suggesting potential reform.

Results

In each Australian jurisdiction, the laws that affect bicycle riders are sourced from numerous legislative instruments. Most jurisdictions have an overarching piece of transport legislation which governs some serious driving offences and authorises the creation of traffic regulations (e.g. *Road Traffic Act 1974* (WA)). State and territory regulations exist in various forms, though all have either wholly, or in part, adopted the model road rules set out in the *Australian Road Rules*. The *Australian Road Rules* were developed by the now National Transportation Commission (NTC) in 1999. The goal of the NTC was to create nationally consistent rules that could be easily understood and adhered to by road users, so as to create safer and more efficient road environments. Detailed analysis of each jurisdiction's road regulations evidenced that the NTC's objectives have been frustrated in some key areas, where reform has not been achieved universally (e.g. provisions for mandatory minimum distances for overtaking bicycles are yet to introduced outside of Queensland). A relatively uniform approach was found across Australia regarding legislation that deals with compulsory third party insurance, tortious negligence, and criminal liability.

Four categories were identified to group the laws affecting cyclist safety – laws governing:

1. Motorist and cyclist equipment,
2. Road sharing interactions,
3. Bicycle specific infrastructure and other special road/road-related features, and
4. Other criminal and civil liabilities of road users.

Category 1 largely consisted of practical measures, such as requiring bicycles to have at least one working brake (e.g. *Road Rules 2014* (NSW) reg 258). Those provisions had the greatest uniformity across all states and territories. The different jurisdictions' approaches to category 4 laws were also relatively consistent. For example, negligence was generally governed by a codification of subsisting common law tests (e.g. *Civil Liability Act 2002* (NSW) s 5B largely codified *Wyong Shire Council v Shirt* (1980) 146 CLR 40).

By contrast, categories 2 and 3 saw some notable distinctions between jurisdictions. Road sharing interactions was the most voluminous category as it concerned laws that relate to how and where all vehicles (including cyclists) can move on the road. Category 3 laws also varied considerably, particularly in relation to the rights of bicycle riders to use footpaths and other pedestrian infrastructure. Secondary sources suggest that policy decisions regarding category 3 laws are often heavily influenced by popular community opinion, rather than any scientific justification based on safety considerations (Phillips, 2014).

The full paper contains a series of comprehensive tables summarising the typology analysis, and an accompanying discussion.

Conclusion

Improving road safety requires more than legislative intervention alone. Road laws will be ineffectual if the public is not adequately educated on their rights and responsibilities, or if suitable infrastructure to facilitate compliance does not exist. However, legislation creates a legitimising foundation for initiatives aimed at improving vulnerable road users' safety, and is therefore a vital piece of the road safety puzzle.

There seems yet to be a legislative panacea for improving cyclist safety. This paper suggests that laws impacting bicycle users' safety can be grouped into four categories. Empirical analysis showed that there is scope to develop laws in each of those categories, as has been progressively done by individual states and territories. By auditing current practices, research can be undertaken to evaluate the efficacy of legislative schemes to iteratively improve the legal framework governing road users' conduct.

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A road safety strategy for Norfolk Island, an Australian external territory [Roed siefti i’ Norf’k Ailen, a’ ekstirnal teritrii o' Ostrielya]

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Abstract

Norfolk Island is an Australian external territory in Oceania. The significant road safety reforms in Australia from the 1970s onward bypassed the island, and most road safety ‘silver bullets’ adopted in other Australian jurisdictions were not introduced. While legislative amendments in 2010 introduced mandatory seat belt wearing for vehicle occupants on Norfolk Island, other critical issues face the community including drink driving by residents and visitors, occupant protection for vehicle passengers, and the provision of a more protective road environment. The release of the first Norfolk Island road safety strategy 2014-2016 proposed, inter alia:

- a lower BAC of 0.05 and the introduction of compulsory driver alcohol and drug testing by police;
- targeted enforcement of occupant protection for vehicle passengers, particularly for passengers riding on vehicle tray backs;
- education interventions to challenge values held by some members of the community that support unsafe road use;
- ensuring that driver information, training and testing is adequate for all drivers;
- identification and rectification of hazardous roadside infrastructure, particularly barrier protection at “high drop locations” within the road network; and
- developing a specification for vehicle standards for vehicles imported into Norfolk Island.

Norfolk Island is engaging in a process of integration with the Australian community, and wider issues relating to funding and resources have impacted on the implementation of the road safety strategy. The response to the strategy will be discussed, particularly in terms of current attempts to address drink driving and the provision of a safer road environment.

Introduction

Norfolk Island is a small and remote Australian external territory of 34.5 square kilometres located in the South Pacific. It is remote, being 1,471 kilometres from Brisbane, 1,673 kilometres from Sydney, 1,074 kilometres from Auckland, New Zealand, and 934 kilometres from Noumea, in the French territory of New Caledonia. The Territory of Norfolk Island comprises three major islands: Norfolk Island, Philip Island, and Nepean Island. Only Norfolk Island is settled. Norfolk Island has a unique history for Australian jurisdictions. There was discontinuous settlement of the island, by Pacific Islanders probably over the period 1,000-1,500 AD, and several British settlements in 1788-1814, 1825-1855, and from 1856. Of these, the Second Settlement, 1825-1855, left a lasting legacy of substantial infrastructure, including public buildings, roads, jetties and bridges. Norfolk Island became a territory administered by Australia in 1913. The island experienced major change and development during World War 2, when up to 2,000 New Zealand troops were garrisoned on the island, an airfield was constructed, and existing roads were widened and re-built. Burnt Pine has become the primary residential and commercial centre for the island, with an administrative precinct at Kingston and an educational precinct at Middlegate. In 2014, Norfolk Island’s residential population was estimated to be about 1,300. It continues to decline as family members leave for Australia and New Zealand for employment and education [1]. At any one time, there may be up to 700 tourists visiting the island (see Note 1 for a brief demographic profile of Norfolk Island).

Norfolk Island is an Australian external territory (see Note 1) and an integral part of the Commonwealth of Australia. From 1979-2015, the island was a self-governing territory under the Norfolk Island Act 1979 (Cth), and the then Norfolk Island Legislative Assembly had wide-ranging powers to make laws, including road transport law and criminal law.

An inquiry by the Joint Standing Committee on the National Capital and External Territories [1] concluded that the current administrative arrangements were no longer tenable. The Committee recommended

> "that, as soon as practicable, the Commonwealth Government repeal the Norfolk Island Act 1979 (Cth) and establish an interim administration, to assist the transition to a local government type body, determined in line with the community's needs and aspirations. This will require the development of a new legislative framework." (p.42)

This recommendation was accepted and agreed upon by the Commonwealth government.

The Commonwealth government is implementing a radical new policy to better integrate Norfolk Island with Australian institutions and to transform the island from a self-governing territory to a modern local government-type authority [2]. In 2015, the Commonwealth parliament introduced a package of eight bills to reform the legal and governance framework for Norfolk Island [3]. The amendments extended Commonwealth administrative law, health care and social security arrangements to Norfolk Island. The Legislative Assembly was abolished (it has been replaced in the short term by an advisory body appointed by the Minister). The reforms amend the Norfolk Island Act 1979 (Cth) to transition the Norfolk Island Legislative Assembly to an elected Norfolk Island Regional Council from July 2016, similar to arrangements in place for the Indian Ocean Territories - Christmas Island, and the Cocos (Keeling) Islands). Under the reforms, the New South Wales government will deliver state-level services and administer applicable New South Wales laws [3].

The road safety situation on Norfolk Island

The development of a safe, efficient and sustainable road transport system for Norfolk Island has lagged considerably behind the other Australian jurisdictions. Other island communities of a comparable size in Australia have either been subject to State or Territory government road safety policies as a consequence of being directly administered by those jurisdictions or, despite being external territories, are subject to relevant State or Territory laws (e.g., Cocos (Keeling) Islands, and Christmas Island).

As noted, over the period 1979-2015 Norfolk Island was unique amongst the Australian external territories as it was self-governing. The relevant road transport legislation is the Norfolk Island Traffic Act 2010.

As at October 2013, there were 2,365 vehicles registered on Norfolk Island, and a further 564 unregistered motor vehicles.

The minimum age for driver licensing on Norfolk Island is 15 years for a motorcycle rider licence (with a maximum engine capacity 185cc), and 15 years 9 months for a learner driver licence to drive a car.

The permissible blood alcohol concentration for Norfolk Island drivers is 0.08% (0.08 grams per 100 millilitres of blood) for full licence holders, 0.00% (zero) for novice licence holders.

The speed limits for roads on the island are low: a maximum speed of 50 km/h in the rural areas, 40 km/h in Burnt Pine, 30 km/h near the school at Middlegate and along the Kingston foreshore, 30 km/h in the Norfolk Island National Park, and 10 km/h within the car park at the airport. All livestock roaming the roads have the right of way. As with the other Australian jurisdictions and in New Zealand, driving is on the left hand side of the road. There is a cultural tradition for drivers to wave to all approaching vehicles, and often to pedestrians at the roadside (the "Norfolk wave").

Currently, there is no formal public transport provision on the island. A taxi service is available, and a free shuttle bus is available to most accommodation providers on the island. Provision of a shuttle bus can also be applied as a condition of approval for major community events.

The most recent GIS survey of roads on Norfolk Island indicates that there are 77.8 kilometres of paved roads. This figure excludes unformed roads and property access. Previous estimates were 67 kilometres of urban and rural roads [4], and 121 km of roads (comprising 90 kilometres of paved roads and 31 kilometres of unpaved roads) [5].

Norfolk Island roads present drivers with a 'country lanes' feel, where the road itself is "self enforcing" for low vehicle speeds. Where improvement of roads has been undertaken to reflect Australian standards, including improving road aspects such as lines of sight, removing roadside structures and vegetation, and improving pavements, the road environment has been altered so that it can be perceived by drivers as supportive of driving at higher speeds. Mission Road and Collins Head Road, both locations of fatal road crashes, present as such higher speed roads.

There are no railways, waterways, ports or harbours on the island. Jetties are located at Kingston and Cascade to support lighterage to ships offshore, usually transferring cargo but upon occasion passengers ashore for day trips from visiting cruise ships). When ships are visiting the island there is an increase in heavy vehicle movements on Taylors Road and into Burnt Pine if the lighter service is operating from Kingston, or more commonly on Cascade Road through Middlegate and thence Queen Elizabeth Avenue into Burnt Pine. As needed, a temporary pier is built at Ball Bay to allow for the landing of heavy motorised machinery and vehicles, see Figure 1.

Figure 1. A temporary pier constructed at Ball Bay to allow for the landing of heavy machinery and vehicles. Photograph by the authors.

After consideration of Norfolk Island's post-war history and the nature of the population change, it seems that the influx of Australian and New Zealand migration occurred at the same time as those countries were engaged in vigorous debate regarding what are now known to be highly successful and necessary road safety measures.

For many residents of Norfolk Island, the road safety reforms occurring in the rest of Australia and in New Zealand seemed superfluous for a small and remote island community. Norfolk Island thus lagged behind in mandatory occupant protection laws requiring the wearing of seat belts (dating from the early 1970s in Australia), and in targeting drink driving through random breath testing and lowering the permissible blood alcohol concentration (BAC) levels for driving (dating from the 1980s in Australia). The possible introduction of such measures was not accepted as part of the values of the Norfolk Island community, and, indeed, islanders expressed some pride that these measures were not implemented on the island, for example, advocating that some tourists were attracted by the absence of mandatory seatbelt laws and the absence of random breath testing.

The road safety challenge on Norfolk Island is considerable for a small and remote community, and has been problematic for some time (see Figure 2).

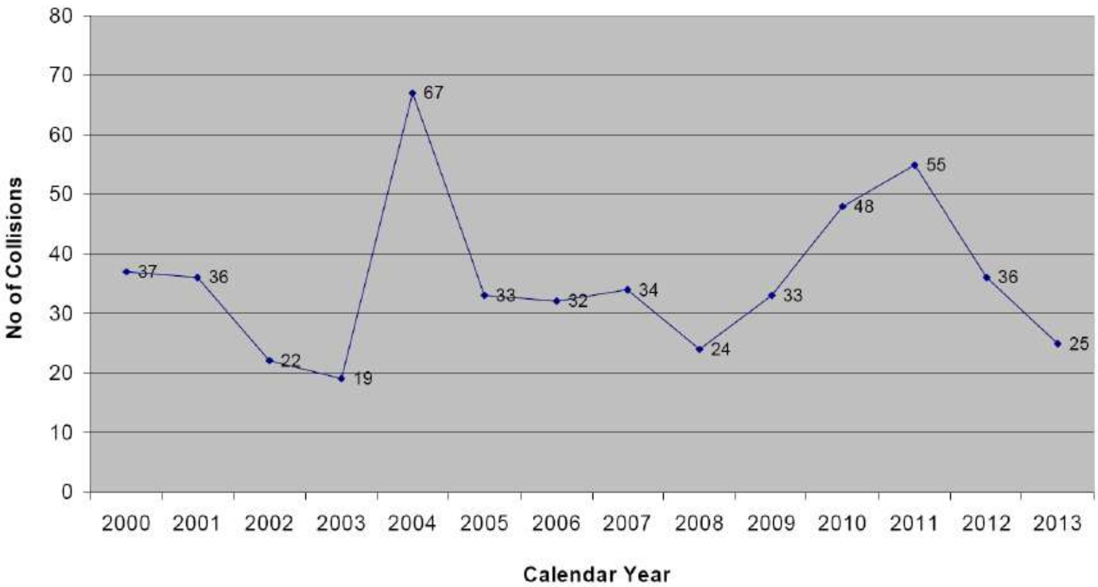

Figure 2: Motor vehicle crashes reported to Norfolk Island police, 2000-2013. From [5])

The financial cost of road crashes on Norfolk Island is of particular concern. For the individual, there can be loss of wages (both for the individual and the family), medical costs if an injury was incurred, the potential voiding of comprehensive insurance (creating liabilities for costs of damage to other property and for medical treatment and psychological injury to other persons), and repair or replacement costs for the vehicle. The financial cost to the island community can be considerable, for example, the cost of medivacs from the island over the period January to July 2013 was $276,000 (of which a portion of the overall costs was attributable to trauma arising from motor vehicle crashes) [5].

Drink driving on Norfolk Island is at crisis level (see Figure 3) [5]. The mean blood alcohol concentration (BAC) in drink drivers over the period 2009-2013 was 0.177% (0.177 grams per 100 mls of blood). Thus over half the drink drivers caught on Norfolk Island over the period 2009-2013 were at levels of alcohol impairment considered high range in other Australian jurisdictions (i.e, above a BAC of 0.15%) .

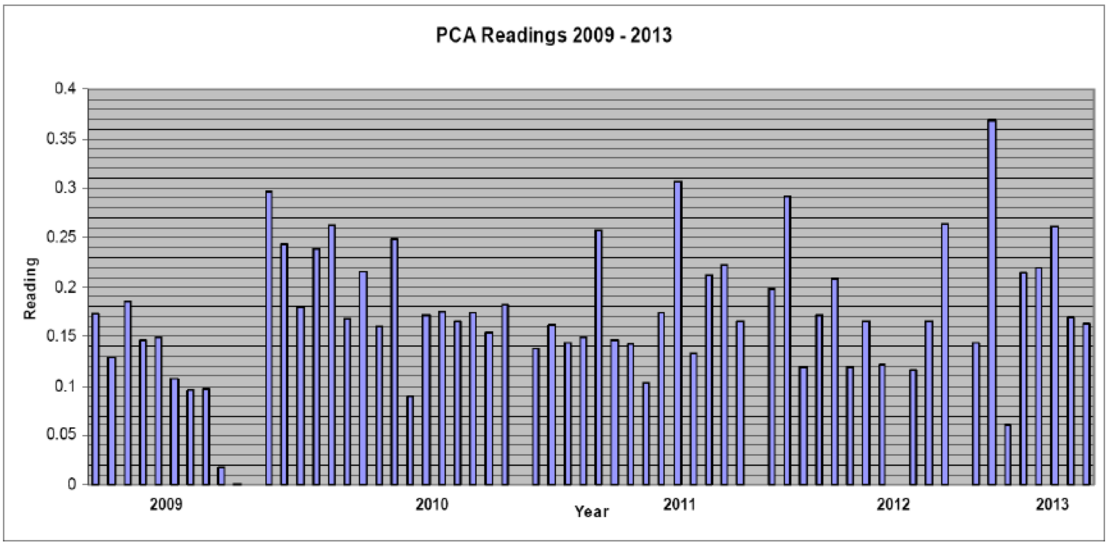

Figure 3: Blood alcohol concentration (BAC) for drink drivers on Norfolk Island, 2009-2013. The red line indicates the permissible BAC level for drivers holding a full driver licence (BAC = 0.08%). From [5]

Such high BAC levels are considered a major driving offence in all other Australia jurisdictions (and can constitute an aggravating factor for prosecutions for driving causing death or grievous bodily harm). The Norfolk Island Police note that these figures do not include the drug readings that were also obtained, of which there were 3 out of the 9 PCA detections in 2013. Evidence of drug use arises when police conduct a blood test as opposed to a breath screening of a driver. This happens when blood tests are used following a collision where the driver is injured (i.e., hospitalised) and/or the breath testing equipment is off island for calibration. Arguably, this indicates that it is likely that a number of drug detections of impaired drivers are missed as police use breath analysis predominantly to screen for impairment.

In part, the reluctance to introduce such known road safety measures as seat belts and random breath testing reflected a wider belief that Norfolk Island was a safe community that was unaffected by issues of violence and crime, unlike other communities in Australia and New Zealand. This belief underpinned, in fact, the promotion of the island as a timeless and safe tourist destination. The last decade, however, has challenged and ultimately negated such a belief, and Norfolk Island has recognised that it is a community that, like others, can be subject to serious crime.

As a result, significant legislative reform occurred. A new Traffic Act 2010 was enacted. Some of the road safety reforms introduced included:

- the introduction of occupant protections laws relating to use of seat belts and the carriage of passengers;
- laws relating to driving under the influence of drink or drugs, the conduct of breath analysis and the powers of the police;
- the introduction of more stringent novice driver licensing provisions;
- laws relating to the use of bicycle helmets; and,
- sundry provisions relating to motor vehicles and driving.

The legislative changes also provided for the establishment of a Road Safety Committee. The committee is a group comprising six persons drawn from the community, the Administration, and emergency services and is established under the Traffic Act 2010 Section 52B. The Registrar is the Chair of the committee and reports to the Minister for Roads (currently a function under the Minister for the Environment). The Act specifies that the Road Safety Committee is to inquire into and make recommendations concerning road safety and such other matters. The committee is required to provide an annual report to the Minister on the operation of the Traffic Act for the preceding year ending 30 June, and its effectiveness. The committee may make recommendations for changes to the Traffic Act 2010 or the Traffic Regulations that may make it more effective in regulating road traffic for the purpose of improving road safety for persons on Norfolk Island.

The strategy development process

The occurrence of serious road crashes resulting in deaths and injuries, together with issues raised as a consequence of police enforcement of illegal behaviour by drivers and their passengers, saw the conduct of a Road Safety Forum in 2013 as a community consultation.

In the Norfolk Island Legislative Assembly, the Hon Ron Ward MLA, Minister for the Environment, stated:

> Road Safety Forum
>
> MR WARD: … Mr Speaker, on the 17th July this year I announced in this house that a Road Safety Forum would be held to seek public input into a full review of road safety issues on this island. The public forum will be held on Wednesday, 23 October 2013 at Rawson Hall between 5.00 and 6.30 pm to discuss road safety issues on the island and to seek community input as to what measures, if any, are considered necessary to adopt or legislate for, to make our roads safer for all road users. This initiative has been put forward by the Road Safety Committee for a community based forum to actively seek input from the public. I urge as many people as possible to attend and be involved. The views of the community are critical to the success of any road safety program. Matters to be addressed at the meeting will include the provision of a driver education program at the school; review of the current restrictions of the ‘L’ and ‘P’ plate driver’s licences; drink driving issues, enforcement of road rules and motor vehicle registration and licensing. This forum is an opportunity to raise awareness of the issues and work through them to find solutions that are acceptable and workable in the Norfolk Island context. The forum will present input from medical officers, ambulance, police and rescue services and actively seeks input from all who have road safety concerns or ideas they wish to have considered. Many in the community may be unaware of the Road Safety Committee. The Committee is group of voluntary local members who give freely of their time to bring a range of expertise and experience together to guide the enhancement of safe road use for all road users. As well as the regular members of the Committee, considerable assistance has been freely given by Mr Ian Faulks who is a nationally recognised expert in road safety matters. I take this opportunity thank Mr Faulks and the registrar Mr Allen Bataille, the emergency services personnel and all who have been working on this project and to those who have agreed to conduct the forum. (Proceedings of the Norfolk Island Legislative Assembly, 16 October 2013, Pages 317-318).

Two goals of the Road Safety Forum were to clearly define community standards and expectations, and to underscore that action must to be taken to address the escalating financial, physical and emotional cost of road crashes and related road trauma. The Forum was held at Rawson Hall, Burnt Pine, on October 2013 and was attended by some thirty concerned local residents.

The forum commenced with the presentation of road safety facts and figures on Norfolk Island, and suggestions based upon academic research and strategies employed in other states and territories as to what a road safety strategy should consider. The Forum was addressed by many speakers, including members of the Legislative Assembly, Norfolk Island Police, St John Ambulance Service, Volunteer Rescue Squad, Legal Services Unit, and the Road Safety Committee. An open and robust debate ensued, with a range of topics discussed and views expressed (for a summary, see Table A).

Table A: Summary of Road Safety Forum attendees' views on questions relating to road safety and the operation of the road transport system on Norfolk Island.

Driver education: 1. poor attitudes towards drink driving 2. poor driving practices, for example, street racing of vehicles 3. improved awareness of the potential dangers involved in driving 4. support for the current development of a school-based driver and road safety program
Conditions of local roads must improve and we must consider more safety features in their design, such as the installation of 'Armco' barriers, redesigning of identified dangerous corners and intersections.
The government needs to ensure that the various road/vehicle/driver based taxes and levies are put back into road maintenance.
There needs to be more public education and road safety awareness campaigns.
Do we have adequate assessment of our drivers, particularly elderly drivers?
More police and more patrols, particularly at night.
Our police need to be supported in their road safety enforcement efforts by the public and government.
Responsible Service of Alcohol policy in our licensed premises should be better enforced so as to have a positive impact upon road safety, in particular drink driving.
Speed limits should be reviewed and enforced.
Seat belts…do or don't we need them? Have they been effective?
The Assembly should consider the introduction of random breath testing legislation
Our Compulsory Third Party insurance (CTP) scheme does not provide the coverage that most people believe that it does and we need to address this.
Public transport. Why can't we have public transport in some form? There was support for the introduction of a 'Booze Bus' for weekends.
Fluorescent tags to be fitted to cows that use grass verges for grazing, so they are easily seen at night.
Parents should accept more responsibility for teaching our kids the right driver behaviour and attitude.
Road safety legislation should be aimed at deterring dangerous practices and attitudes, specifically speeding and driving whilst intoxicated, and not merely impact upon the civil liberties of safe drivers.
Road safety campaigns should focus on promoting self-compliance with road safety and punish dangerous and intoxicated drivers severely.
It was also noted to the forum that whilst there are many areas of road safety that we can improve on, there are also a number of positives about the road safety culture on Norfolk Island, such as excessive speed – we don't see the prevalence of it on Norfolk that other small jurisdictions do; seatbelts – given their history on Norfolk and the relatively short time since

their introduction, compliance levels are reasonable (with room for improvement).

Following the Road Safety Forum, and with the support of the Road Safety Committee, it was determined that a road safety strategy for Norfolk Island was required. It was agreed that the road safety strategy would be aligned with the National Road Safety Strategy 2011-2020, and thus would reflect the Safe System approach.

A review of road safety in small island communities in Australasia

To assist the development of a road safety strategy for Norfolk Island, a scan of small Australasian island jurisdictions was conducted to identify any road safety strategies that may have been developed. The small Australasian island communities included:

- the Australian external territories of Cocos (Keeling) Islands and Christmas Island
- Kangaroo Island in South Australia;
- King Island, Flinders Island (Furneaux Group), and Bruny Island in Tasmania;
- Magnetic Island, Fraser Island and Palm Island in Queensland; and
- the New Zealand islands of Stewart Island and the Chatham Islands

No island community had a road strategy of the form envisaged for Norfolk Island, but there were relevant aspects of a road safety strategy that were identified.

For example, the Flinders Council and the Flinders Island District High School developed a Transition program to assist island children in their transition away from the island and to lessen the impact on the community [5]. Students undertake many activities that will provide them with the skills to enable them to live independently once they leave the island. There are life skills programs in road safety; financial literacy; budgeting; a Party Safe program; personal safety; job applications; mock interviews and social skills. The island's Year 10 students visit the University of Tasmania and socialise with Newstead College students in Launceston. There is an orientation trip to metropolitan areas, linking students to support services; driving lessons, public transport, college orientations, sport and recreation and regular drug and alcohol free social events. Newstead College students act as mentors to the island students during their first term at the College to help them make the transition. The overall objective is to help the Island students successfully transition to further education and training and to adapt to living away from home at a young age.

On King Island, the King Island Council and the Tasmanian Department of Infrastructure, Energy and Resources established a community road safety partnerships (CRSP) program [5]. The King Island Safety Committee was identified as the key advisory body to coordinate projects. The committee had already developed a community safety plan 2007–2010, which had road safety issues included. The King Island safety committee's main focus has been awareness campaigns to address road safety involving motorcycles, drink driving and driving to conditions. A formal Memorandum of Understanding was signed between the council and the Department in September 2008. With regard to school education, "Road Risk Reduction" teaching resources for pre-learner driver education were shared with the school and a "Keys to Ps" parent session for supervisors of learner drivers was conducted. The community road safety partnerships program provided motorcycle safety posters and brochures for use by the King Island Safety Committee's community education program. During the 2008-09 Christmas holiday period King Island experienced several crashes with drivers using hire cars, particularly while driving on the island's gravel roads. The King Island Safety Committee developed a new initiative to promote driving to conditions using rear vision mirror tags. The tags which display the messages "Drive to Conditions, Keep Speed Low on Gravel Roads" and "Buckle Up", were placed in hire car vehicles and fleet vehicles.

The New Zealand Transport Agency produced a road safety issues report for the Chatham Islands Council [6]. The report was produced to provide the evidence base to enable the Council to develop ways to reduce road deaths and injuries in the Chatham Islands, and is a good example of road safety data collection and reporting.

The Norfolk Island Road Safety Strategy 2014-2016

The road safety strategy for the next few years on Norfolk Island – the Norfolk Island Road Safety Strategy 2014-2016 [5] – recognises that despite our best efforts, several people will be injured severely in road crashes, and perhaps an islander or visitor may be killed. The strategy outlines the critical issues facing the Norfolk Island community, including:

- Collection and reporting by annual publication of statistics for road safety performance and reporting on the general operation of the road transport system;
- Continuing use of the Road Safety Committee and the Youth Assembly as primary consultative mechanisms to address road safety issues, including the Road Safety Committee's role in the collation of annual road safety and road trauma statistics, and the Youth Assembly's role in reviewing and redrafting the Norfolk Island Road Handbook;
- Drink driving by Norfolk Island residents and visitors, particularly drink driving at excessively high blood alcohol levels (over 0.15 BAC);
- Addressing drink driving in the context of a general public health strategy relating to alcohol use on Norfolk Island, including responsible service of alcohol in licensed premises, provision of alternative transport (shuttle bus), and development of health and judicial interventions for problem drinkers;
- The need for targeted enforcement of occupant protection for vehicle passengers, particularly for children and adults riding on vehicle tray backs;
- The need for targeted enforcement of speeding by drivers, particularly for drivers of vehicles where children and adults are riding on vehicle tray backs;
- Ensuring that driver information, training and testing on Norfolk Island is adequate for all drivers, including novice drivers and riders, older drivers, and visitors to the island;
- Introducing a traffic offenders intervention program as a pre-sentencing option for use by magistrates in determining appropriate punishment for traffic offences;
- Using school-based education and public education and awareness interventions to challenge values held by some members of the community that support or promote inappropriate and unsafe road use on Norfolk Island;
- Using school-based education and public education and awareness strategies to promote the positive benefits of safer road use for the island community and for visitors to Norfolk Island;
- Preserving the "country lanes" aspect of Norfolk Island roads where the road itself is "self enforcing" for low vehicles speeds, while improving the roads to reflect Australian standards;

- Conduct and maintain a road safety audit of the Norfolk Island road transport system, including signage, lane markings and other road markings;

- Identification and rectification of hazardous roadside infrastructure through replacement, relocation, and provision of barrier protection;

- Ensuring that adequate roadside barrier protection systems are installed at locations within the Norfolk Island road network where there are embankments and hillsides with high or steep drop offs;

- Ensuring that where the Norfolk Island road network is adjacent to vulnerable community venues or historic sites there is provision of appropriate and adequate roadside barrier protection systems;

- Passage of a legislative reform package that includes, but is not necessarily limited to:
  (a) a lowering of the legal blood alcohol level to 0.05 BAC, commensurate to other Australian jurisdictions, and providing for a mandatory requirement for drivers to submit to alcohol and drug screening as directed by police;
  (b) provision of a general power for police to stop vehicles, without prior suspicion of an offence occurring;
  (c) reform of the compulsory third party (CTP) insurance scheme to address problems relating to the availability of insurance for personal liability for all road users, and the viability of the CTP scheme;
  (d) reform to the driver licensing law to allow for recognition of non-Norfolk Island learner and provisional (probationary) driver licences; and
  (e) developing a specification for vehicle standards for vehicle imported into Norfolk Island, based on what is considered acceptable for importation and use within the island’s road transport system.

Figure 4: The ‘country lanes’ aspect of Norfolk Island (Anson Bay Road). From the authors.

The outcomes

The Traffic Act Amendment Bill 2014 (Traefik (Chienjen) Bil 2014)

The Norfolk Island Road Safety Strategy 2014-2016 was Tabled in the Legislative Assembly of Norfolk Island in September 2014, but was not debated at that time.

In line with the strategy, the Traffic Act Amendment Bill 2014 was introduced in October 2014. The Bill was an initial step towards bringing the road traffic laws of Norfolk Island more in line with accepted principles of safety applied in the Commonwealth. The Bill made provision for random breath and oral fluid testing of drivers, and provides police with the powers to stop a driver and administer an alcohol or other drug test. In particular, Section 32A provides a power to conduct random breath testing. A police officer can request any person to take a breath test if the officer is satisfied that the person is or was driving a motor vehicle on a road or otherwise in a controlling position with respect to the vehicle or the driver. Before a breath test is done a police officer may require a person to take a preliminary breath test to ascertain if there is any indication of alcohol in the person's breath. A police officer may require a person to stop a vehicle and if the driver does not do so an offence is committed. Section 32B provides that a person may be arrested if as a result of the testing the alcohol concentration exceeds those set out in the section. Section 32C provides for the conduct of random testing of oral fluids for prescribed illicit drugs. The provision mirrors that for alcohol testing. Section 32D provides for the arrest of persons testing positively for illicit drugs and mirrors the provision for alcohol testing. Section 32 E makes provision for having oral fluid samples tested following the arrest of a person. Section 32F provides for the taking of a blood sample in order to determine the presence of illicit drugs.

The introduction of the Bill was contentious, and it was referred to the Impact of Bills and Subordinate Legislation Committee to enable further public consultation on the proposals for the introduction of random breath testing of drivers for alcohol and illicit drugs and the lowering of the acceptable blood alcohol threshold from 0.08 to 0.05. The Committee tabled an interim report in early 2015 [7], and its final report in March 2015 [8].

The community responses received in written submissions or public hearings opposed some or all of the proposed amendments. The introduction of drug testing was the exception, as most expressed approval of this proposed legislative measure. The consistent theme of concern was that changes to drink driving laws on Norfolk Island would significantly affect commercial tourism and hospitality operations, as well as islander social practices.

Nonetheless, the Committee did support the introduction of random breath testing and drug testing of drivers.

However, it did not support the proposed reduction in the permissible BAC from 0.08% to 0.05%. The Committee commented:

> The advice of the NI Police to revise the acceptable PCA threshold at a later stage once the community has adjusted to RBT is supported on the basis that there is an evaluation after a period of 2-3 years when specific data has been collated to allow an informed assessment of the risk profile to determine whether a reduced PCA is actually necessary. This will require a more robust system be put in place that records all testing information, including readings below the prescribed thresholds, and information regularly published for wholesale access. Stakeholder representation before the Committee signalled potentially serious consequences for commercial operations, events that support the islands tourism industry, as well as unique island activities including community fundraising efforts. Safety nets to protect against or offset the

> consequences spoken of need to be addressed before policy changes are introduced. (p.20) [8]

The Traffic (Amendment) Bill 2014 was passed in amended form in April 2015, providing for the introduction of random breath testing and drug testing, but retaining the existing legal BAC level for drivers (less than 0.08%).

The Norfolk Island Road Safety Strategy 2014-2016 was also formally adopted by the Legislative Assembly of Norfolk Island in April 2015.

Roads strategy development

A second important development from the strategy is the conduct of a road safety audit and development of a roads strategy. Action in this area reflected the Commonwealth government's concern about the standard of the current road infrastructure as well as endorsement by the Commonwealth of a recommendation of the Joint Standing Committee on the National Capital & External Territories to complete an upgrade of the Cascade Pier. Two projects are underway: a review of roads on Norfolk Island by WorleyParsons; and a project to extend Cascade Pier to provide a safer operating environment for passenger and freight movements as well as providing a launching point for commercial and recreational fishers (also by WorleyParsons). Of the two piers on Norfolk Island, Cascade Pier is used for the majority of shipping operations.

Figure 5: The intersection at Middlegate. The freight routes from Cascade Pier and Kingston Pier use this intersection. Cattle have right of way on Norfolk Island roads. From the authors.

The WorleyParsons review of Norfolk Island roads [9] confirmed the concerns raised by Faulks [5], particularly for the Middlegate precinct where freight movements and school travel intermix with general road use by islanders. The road infrastructure was found to be in good condition generally, but the road audit did identify serious structural defects with the Bay Street Bridge within the Kingston and Arthurs Vale Historic Area, and the bridge was closed immediately for repair work.

The future

As noted, the Norfolk Island Road Safety Strategy 2014-2016 was formally adopted by the Legislative Assembly of Norfolk Island in April 2015, together with passage of the amended Traffic Act Amendment Bill 2014. However, the Traffic Act Amendment Act 2015 was not promulgated prior to the passing of reform legislation in the Commonwealth parliament to amend the Norfolk Island Act 1979.

The introduction of random breath testing and drug testing for impaired drivers on Norfolk Island has thus been left ‘stranded’, and further action will be required by the Norfolk Island Administrator by Ordinance to progress these matters. At this point, there is no indication as to when such an action may be taken.

There are significant changes facing Norfolk Island following the passage of the amending Commonwealth legislation, including determining the form of the Norfolk Island Regional Council and the phasing in of New South Wales laws as necessary. The Hon. Jamie Briggs MP, Assistant Minister for Infrastructure and Regional Development, noted that the application of state law necessitated:

> “… keeping in mind the need to prioritise economic development, community safety and sustainable government while responding to the unique circumstances on Norfolk Island.” (Letter to Norfolk Island residents about the reforms, 14 May 2015, p.1)

It would seem that the Commonwealth Government’s policy on Norfolk island is in line with that of the Indian Ocean Territories (Christmas Island, and the Cocos (Keeling) Islands, namely for incorporation into an existing State or Territory. In the case of the Indian Ocean Territories, this is with Western Australia; for Norfolk Island, it is with New South Wales. Legislative, administrative and institutional frameworks in these territories will likely be generally aligned with those in place for remote communities on the Australian mainland.

The Traffic Act 2010 (Norfolk Island) will, at the least until 1 July 2016, continue to be in force. The new Section 16A of the Norfolk Island Act 1979 (C’th) ensures that any Legislative Assembly laws that were in force immediately before the interim transition time continue in force. However, a mechanism for applying New South Wales laws has been created. A new Section 18A allows for the application of New South Wales laws to Norfolk Island. Norfolk Island laws can be amended or repealed by a section 19A Ordinance (Madden, 2015). Whether New South Wales will amend or repeal the existing road transport legislation is unknown at this time. Some aspects, such as the introduction of random breath testing and drug testing for impaired drivers, and reducing the permissible BAC level to less than 0.05% for general drivers are desirable. Other aspects, such as the unique occupant protection laws, driver licensing and vehicle registration laws, and standards relating to vehicle construction, the management of roads, footpaths and bridges, and the provision of street lighting, would seem to merit a more considered judgment.

The existing road safety strategy [5] has a putative concluding date of 2016, and it would thus be expected that an evaluation of the strategy and the development of a new replacement road safety strategy would be scheduled for after 1 July 2016, when New South Wales laws will begin to be phased in and an elected Norfolk Island Regional Council has been established.

Acknowledgements

The authors express their appreciation to the Hon. Ron Ward, then Norfolk Island Minister for the Environment, and Mr Allen “Ikey” Bataille, Registrar, Norfolk Island Administration, for their assistance during the period of the development of the strategy and its formal adoption by the Legislative Assembly of Norfolk Island.

Notes

1. The Australian external territories are the Ashmore & Cartier Island, the Australian Antarctic Territories, Christmas Island, the Cocos (Keeling) Islands, the Coral Sea Islands, and Norfolk Island. Of these, Christmas Island and the Cocos (Keeling) Islands (together termed the Indian Ocean Territories) and Norfolk Island are the only territories to have permanent residential settlements, a road transport system, and the legal infrastructure of an inhabited state (such as police or courts). The remainder have only transient inhabitants.

2. Norfolk Island has retained an impressive Georgian architecture associated with the Second Settlement, 1825-1855. The Kingston and Arthur's Vale Historic Area on Norfolk Island is an outstanding example of Australian colonial landscape, and has World Heritage listing. Kingston is the administrative centre on the island, while Burnt Pine has developed as the major commercial area. A smaller educational precinct is located at Middlegate. Norfolk Island Airport is the sole airport on the island. With the development of commercial air travel in the 1960s, there was an influx of new residents from Australia and New Zealand, and a regulatory immigration system was imposed from the late 1960s until 2013. The influx of "mainland" settlers (bringing their financial capital) saw tourism develop as a new industry, with a focus on colonial penal history, the Bounty Mutiny historiography, and duty-free shopping. The age profile of the Norfolk Island community is notably older than the rest of Australia, with a median age of 46 years, as compared to 37 years on the mainland. The main age differences were for those aged between 15-34 years, and those between 55-74 years [10]. About two-thirds of the population were born in Australia, including about one-third who were born on Norfolk Island itself. A survey of more than 80% of the island population in 2011 found significantly higher labour force participation and significantly lower unemployment than in Australia generally. Females were proportionately greater participants in the labour force than elsewhere in Australia. A greater proportion of persons on Norfolk Island were employed full-time, and, again, females were better represented among the fulltime employed, compared to elsewhere in Australia. However, the levels of financial stress on Norfolk Island were higher than elsewhere in Australia, with 51% reporting that they were 'just getting by'; 27% reporting that they had missed a utilities bill; and 11% stating that they could not pay their rent or mortgage on time. Despite this financial stress, overall, Norfolk Island residents reported a high level of overall satisfaction with life – noting the financial situation and employment opportunities.

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A new Approach to Evaluating New Vehicle Safety Technologies using Meta-Analysis

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Abstract

This study reports on a collaborative research program initiated by Euro NCAP that explores the possibility for evaluating new safety technology using multiple databases. The Validating Vehicle Safety through Meta-Analysis (VVSMA) group comprising a collaboration of government, industry, consumer organisations, and researchers. Aggregate analyses of data pooled from a number of jurisdictions is combined to evaluate active safety technologies. An exemplar analysis of low speed AEB City technology is included using a standard rear-end crash analysis format and the established Multiple National Database Study (MUNDS) approach. Quasi induced exposure was employed to control for extraneous factors. The results showed that AEB City technology led to significant reductions in crashes overall, although individual jurisdiction analyses failed generally to show significant reductions in rear-end crashes. A second study to evaluate Lane Departure Warning (LDW) and/or Lane Keeping Assist (LKA) is currently underway and is expected to report on its findings early next year. With a substantial increase in available data, statistically significant real-world findings were obtained within much shorter timeframes. The meta-analysis approach using data from many jurisdictions is a unique contribution to the evaluation of vehicle safety technologies.

Introduction

The safety of modern passenger cars has improved substantially in recent years. The reasons for this improvement include international vehicle regulations that specify minimum levels of occupant protection, and consumer tests that rate vehicle safety (Stucki, *et al*, 1996; Broughton *et al*, 2000; Ward, 2012; Newstead *et al*, 2013). Improvements have come from greatly improved vehicle structures and materials, as well as new safety technology to better restrain the occupant in a crash and to mitigate against serious injuries. This passive safety approach has focused on preventing injuries, rather than stopping the collision or mitigating injuries. More recently, industry and government initiatives have shifted their focus to improving active safety in vehicles (Giebel *et al*, 2008). In-vehicle safety technologies aimed at preventing the crash are developing fast across the world, driven by the market place, rather than in response to new regulations. However, there is only a limited understanding of the possible (and actual) benefits for most of these systems. An outline on how these active technologies are expected to work is illustrated in Figure 1.

For new systems there are often benefit analyses done based on target population estimates and laboratory verifications of these systems. However, in the hands of everyday drivers the systems may have a different performance. Real world benefits of active safety technologies, are often hampered by the lack of sufficient real-world crash and non-crash data to obtain early and reliable effects of new innovative safety systems in cars. There are simply not enough systems available in each market individually to conduct these analyses. One way of potentially speeding up this process would be to investigate the possibility of collecting and analysing crash data on a broader basis than one jurisdiction can conduct from their limited crash numbers.

To address this problem, a new approach was developed using a meta-analysis approach, the established Multiple National Database Study (MUNDS) method (Fildes *et al*, 2013) where those with suitable data from various jurisdictions, conduct their own analysis using a common strategy, and these are then pooled together to form a better estimate of effects of car technologies.

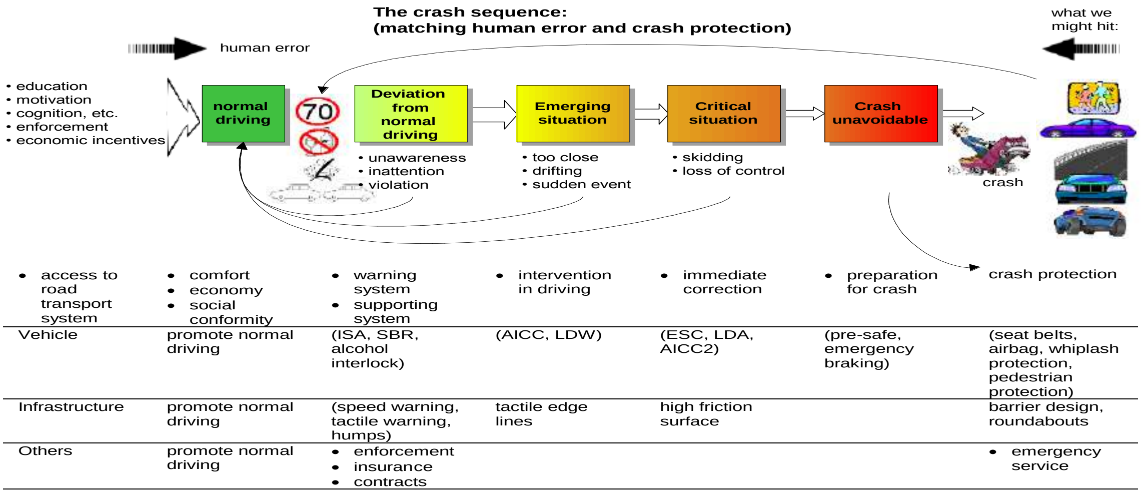

Figure 1. The integrated safety chain

The benefits with this approach are several. First, by pooling, a larger amount of data becomes available, allowing for early analysis of a new system performance, and much sooner than any one jurisdiction can provide. Second, results can be generalized across jurisdictions, still allowing national variation and comparison. Moreover, no raw data needs to be given away from the national statistics of each jurisdiction. To help guide manufacturer, government, and consumer group judgments about which technologies ought to be encouraged, it is critical to establish their potential savings in crashes and injury mitigation. It is expected this will help encourage their introduction and ensure market penetration is optimized.

The VVSMA Consortium

To address this need, the Validating Vehicle Safety using Meta-Analysis (VVSMA) consortium was formed under the auspices of Euro NCAP to conduct analyses of the safety benefits of two emerging technologies, namely AEB City, and Lane Departure Warning (LDW) and/or Lane Keeping Assist (LKA) using the MUNDS approach. The VVSMA consortium involved a number of government, industry, consumer groups and research organisations from Sweden, France, Germany, UK, Italy, Netherlands, and Australia (Table 1) and commenced their activities in 2012. The European Automobile Manufacturer's Association ACEA maintained a watching brief on the consortium's deliberations.

Police data from six jurisdictions with a

Table 1: Members of the VVSMA Consortium

Member	Organisation
Claes Tingvall - Founding Chair	Trafikverket, Sweden
Anders Lie - Chairman	Trafikverket, Sweden
Michiel Van Ratingen - Host	Euro NCAP, Belgium
Brian Fildes - Secretariat	ANCAP, Australia
Nils Bos	SWOV, Netherlands
David Brookes	Thatcham, UK
Sebastian Döering	VW, Germany (ACEA)
Michiel Keall	MUARC, Australia
Anders Kullgren	Folksam, Sweden
Olaf Jung	BMW, Germany (ACEA)
Yves Page	Renault (ACEA), France
Lucia Pennisi	ACI, Italy
Claus Pastor	BASt, Germany
Matteo Rizzi	Folksam, Sweden
Simon Sternlund	Trafikverket, Sweden
Johan Standroff	Trafikverket, Sweden
Pete Thomas	Loughborough, UK (DfT)

common core analysis format were used in these analyses. Quasi induced exposure was employed to control for extraneous factors across these databases. A major challenge with the approach was identifying crashed vehicles with and without the technology in each database and having the necessary analytic variables. Identifying the crashes that are potentially influenced by the safety system was also important. For reasons of maintaining confidentiality, it was agreed that the individual results for each jurisdiction would not be identified in any subsequent analysis.

Police data from six jurisdictions with a common core analysis format were used in these analyses. Quasi induced exposure was employed to control for extraneous factors across these databases. A major challenge with the approach was identifying crashed vehicles with and without the technology in each database and having the necessary analytic variables. Identifying the crashes that are potentially influenced by the safety system was also important. For reasons of maintaining confidentiality, it was agreed that the individual results for each jurisdiction would not be identified in any subsequent analysis.

Methodology

There were a number of steps involved in the MUNDS analysis process. First, was the need to identify which vehicles in each jurisdiction's database had the relevant technology fitted. As Low Speed AEB technology was offered as a standard feature on several particular makes and models, it was possible to simply identify these vehicles by make and model year in the crash data which were then nominated as "case" vehicles.

For comparison, it was necessary to identify similar vehicles that did not have the technology fitted, and these were labelled as "control" vehicles. Care was taken to ensure that the controls comprised a number of vehicles that embraced the range of case vehicle types (body designs, masses, similar market categories, and so on. As active technologies are designed to work on specific crash types, it was important to restrict the analyses to only those "sensitive" crash types. This was agreed upon from the experience of the members of the consortium and other available sources. A quasi induced exposure measure, described by Chandraratna and Stamatiadis (2009), was included, matching both sensitive and non-sensitive crash situations. The appropriate formula for making these assessments as recommended in Keall & Newstead (2009) was:

$$\textbf{Effectiveness (E)} = 1 - (A/B) / (C/D)$$

where:

A= AEB fitted vehicles as **striking** vehicle
B= AEB fitted vehicles as **struck** vehicle
C= Non-AEB vehicles as **striking** vehicle
D= Non-AEB vehicles as **struck** vehicle

Once the parameters of the analysis were defined, the various data providers then conducted their own analyses and provided these for inclusion in the meta-analysis. Other factors that might have a bearing on the analysis such as the speed of the crash were also identified and adjusted for in the analysis procedure. Further factors such as driver age and sex can also be controlled for, as in an analysis of ESC effectiveness (Fildes *et al*., 2013).

Meta-analysis is a standard statistical procedure involving logistic regression and data merging techniques that estimate the relative rate of sensitive crashes for the case vehicles compared to that of the equivalent control vehicles. The meta-analysis was weighted by the inverse of the variance of the effectiveness measure for each jurisdiction (as is standard in meta-analysis) and tested for the homogeneity of the effect size. Where possible, separate analyses can be conducted for road type and speed zone if needed to further explain the range of effectiveness of the technology.

The work of the consortium comenced late in 2012 and many of the early months involved identifying suitable data, defining the process, and understanding the method. As most of the members of the consortium were new to the approach, it required time for them to appreciate it and the techniques involved.

Exemplar Analysis – AEB City Effectiveness

To demonstrate how the meta-analysis approach works, an example of a recently published analysis by the VVSMA group is shown below. It involved an effectiveness of low speed Autonomous Emergency Braking (AEB City) technology. A paper containing the full details of this analysis was published recently in the Accident Analysis and Prevention journal (Fildes *et al*, 2015). A synopsis of the detailed findings is included below.

AEB City Functionality

CarAdvice (2014) noted that Low Speed AEB or City Safe technologies are marketed under a variety of names, including City Brake Control (Fiat), Active City Stop (Ford), City Emergency Brake (Volkswagen) and City Safety (Volvo). As their names suggest, this type of Autonomous Emergency Braking technology is geared towards low speed situations, generally between 30km/h and 50km/h. These systems rely on various types of sensors detecting an emergency situation and apply the brakes as needed. They tend to work most effectively over short distances, usually 12m or less (CarAdvice, 2014).

AEB City Results

The findings in Table 2 showed a strong and significant reduction in rear-end striking crashes for vehicles fitted with the technology over those that didn't. While the benefits were mainly in low speed urban areas, there seemed to be a small, non-significant, benefit in rural areas too, although this needs further research, given there were very few cases and the likelihood that rural rear-end crashes are relatively rare.

Table 2: Findings for the crash reductions for vehicles fitted with AEB City in rear-end crashes

Jurisdiction	Crash Type	AEB	Non-AEB	Effectiveness	Lower Limit	Upper Limit
Region 1*	*Striking vehicle* *Struck Vehicle*	21 84	202 435	46%	11%	68%
Region 2	*Striking vehicle* *Struck Vehicle*	1 4	138 246	55%	-303%	95%
Region 3	*Striking vehicle* *Struck Vehicle*	14 16	434 374	23%	-57%	64%
Region 4	*Striking vehicle* *Struck Vehicle*	35 59	404 450	34%	-3%	57%
Region 5	*Striking vehicle* *Struck Vehicle*	15 24	105 95	43%	-14%	72%
Region 6	*Striking vehicle* *Struck Vehicle*	2 1	85 82	12%	-2069%	83%
Overall Results*				**38%**	**18%**	**53%**

*Statistically significant results

However, while the overall meta-analysis was highly significant, most of the individual jurisdiction analyses failed to reach significance in their own right (apart from Region 1). This confirmed the need for, and advantage of, the meta-analysis approach used here. While the meta-analysis was able to show the effectiveness of the technology in a relatively short period of time, it would have taken considerably more years for most of these jurisdictions to report on the benefits of the technology based on real-world crash data. In short, it confirms the need and advantage of the approach in conducting real-world evaluations of the benefits of emerging active safety technologies.

Exemplar 2 - Lane Departure Warning Effectiveness (LDW/LKA)

A second analysis is currently being undertaken by the VVSMA group, examining the effectiveness of Lane Departure Warning (LDW) and/or Lane Keeping Assistance (LKA) systems. These are designed to warn a driver when the vehicle begins to move out of its lane (unless a turn signal is on in that direction) on roads and highways or apply positive feedback to correct these encroachments. These systems are designed to minimize accidents by addressing the main causes of collisions on rural roads, namely driver error, distractions and/or drowsiness. The identification of these technologies in the crash data presented a challenge as most vehicles on the road offer these technologies as “optional” equipment, making it difficult to identify vehicle makes and models that have the technology onboard in the crash databases.

In Europe there are very few cars where LDW/LKA is standard equipment currently. In addition, there are other issues such as being default-off. It is not possible to be sure that the system is operating from the crash data and cannot automatically assumed to be active when the vehicle is in use. The expected overall effectiveness is therefore will be lower and generally difficult to identify in these data.

As far as the fitment is concerned, this requires access to the Vehicle Identification Number (VIN) of the crashed vehicles that are known to offer the technology and then to match the particular VIN with the presence or absence of the technology. This complicated procedure involves gaining access to VIN details of the individual make and models of each potential case vehicle to identify cases (fitted) as well as the controls (not fitted) and then manually checking each potential relevant case. VIN is not freely available in most databases. As the VIN is uniquely linked to a car and its owner, there are privacy implications in use and hence, both industry and governments are sensitive to its use. This makes the analysis process difficult, but not impossible – some jurisdictions do list VIN and there are some data sources that can help identify the fitment of optional safety equipment from the VIN. The VVSMA consortium is currently working towards overcoming these challenges and ensuring that the real-world effectiveness of LDW/LKA can be established using the meta-analysis approach.

Discussion

There are various methods adopted to estimate the likely effectiveness of new safety technologies. The auto industry for instance invests considerable resources in developing forecasting (prospective) systems based on simulations of real accidents, using traffic, vehicle and driver models (Page *et al*, 2015). This pre-production “Prospective Effectiveness Assessment for Road Safety (PEARS)” approach relies on virtual analyses by means of simulation, assuming various driver behavioral characteristics. Alternative approaches, such as the MUNDS method used by the VVSMA consortium, analyses real-world crash data to assess the post-production safety benefits of these technologies.

On-road data analyses are always the ultimate test of the real-world effectiveness of these new technologies, although pre-production methods are still very useful in determining priorities and justifying the fitment of these new technologies. This is not to say that one method is superior to another as both methods are complementary. It depends what purpose and priority is required in terms of choosing which technique is suitable.

Meta-analysis is a procedure that is frequently used by medical researchers in establishing the extent of medical conditions and successful treatments, using published randomised controlled trials and clinical controlled studies. The most well-known application of meta-analysis publications in the medical field is the Cochrane Reviews that through meta-analysis, provides evidence-based health care findings based on best available research evidence (Cochrane Collaboration (2014).

The medical approach, however, relies on published studies that fit their criteria, and hence is subject to long delays in evaluation time. The established Multiple National Database Study (MUNDS) approach adopted by the VVSMA consortium speeds up these evaluations by assembling multiple independent aggregate analyses from several jurisdictions using a common study design. This brings together a much larger pool of data than any one jurisdiction has available and speeds-up the process of evaluating safety technologies.

The evaluation of Low Speed Autonomous Emergency Braking (AEB City) in rear-end striking collisions was a successful first attempt by the VVSMA Consortium using the meta-analysis approach. As noted earlier, the analysis found a significant 38% reduction in rear-end striking crashes for vehicles fitted with the technology. It was facilitated by the relatively easy identification of target vehicles in these databases, given that the technology was standard equipment. The second analysis of Lane Departure Warning technology currently underway has additional challenges in that this technology is only fitted to some vehicles as optional equipment. This was discussed in some detail in an earlier section.

The need for early evaluation of these technologies was noted. They promise substantial benefits in reduced crashes and mitigating injuries yet very few can support these claims using real-world crash data. In an earlier report by Fildes *et al* (2013), they noted that the evaluation period can be reduced by half, using the MUNDS approach which means that these evaluations can play an important role in demonstrating real reductions in road trauma and motivation for their widespread fitment to the whole vehicle fleet. Moreover, early findings may also highlight the need for modifications and/or fine tuning to improve their effectiveness. It is critical to establish their likely crash benefits to help guide manufacturer, government and community judgments about which technologies should be pursued to encourage their widespread introduction and ensure maximum market penetration.

Finally, the collaborative approach adopted in this work through Euro NCAP proved to be both positive and productive in achieving its aims. Bringing governments, OEMs, NCAP groups and researchers together to address a common objective led to a creative and innovative evaluation that otherwise would not have been possible.

Limitations

There are limitations with this meta-analysis approach that need to be noted. First, the databases used in this AEB City study inevitably differed in terms of the way and accuracy of data collection across each of the regions. Some data contain a higher proportion of minor collisions to others and police attendance at these crashes was likely to vary. The composition of the vehicle fleet and the crash patterns can differ from region to region. While this was unlikely to have affected the results, it does reveal national data differences across jurisdictions. To the extent that the focus crashes are subject to the same sorts of reporting errors as the control crashes, the effectiveness formula can be expected to adjust for any such jurisdiction biases.

As each database is inevitably structured around local definitions and variables, it can be difficult to undertake a range of additional analyses beyond the core analysis. Again in the low speed AEB analysis, the use of side impacts as an additional quasi induced exposure approach was not possible as these crash types could not be identified in all databases.

As the vehicle fleets differed across jurisdictions, these findings may not be representative of the effectiveness in any one region. This is not necessarily a major problem for the analysis though as the findings probably have more relevance overall than a series of single studies from individual jurisdictions. This adds to decisions about the need for widespread international fitment of these technologies even stronger.

Finally, in conducting these meta-analyses, it is assumed that the benefits calculated in these univariate analyses are for the technology under examination. Yet, as vehicle safety technologies increase and become integrated with others, there is the potential for the benefits to be confounded. While the VVSMA approach is aware of this possibility and has taken this into account to some degree in the selection of sensitive crash types for the AEB City and LDW/LKA effectiveness studies, nevertheless, this will present an additional challenge as the extent of these integrated systems expands. The means of addressing these potential confounding effects in meta-analysis is beyond the scope of the work conducted to date and warrants further research.

Conclusion and Recommendations

In conclusion, the use of the meta-analysis approach by the VVSMA consortium is seen as a valuable and important technique for evaluating new active safety technologies. The results showed that while individual jurisdiction analyses were unable to show significant reductions in crashes for the AEB City technology, statistically significant reductions were obtained from the meta-analysis due to the increase in the amount of data. The approach to pool individual analyzes to achieve a common result worked well without the need to share data records. In addition, the collaborative approach between governments, industry, consumer groups, and researchers was successful with high levels of cooperation. The main challenge when evaluating new safety systems is to get an early and robust indication of the real world performance in traffic. Often, the virtual predicted benefits of new technology can be influenced by human intervention. With a substantial increase in available data, statistically significant real-world findings can be obtained within much shorter timeframes using the meta-analysis approach. A major challenge is to identify vehicles with a specific safety feature when it is only offered as optional equipment. This paper has presented a bold new approach to evaluating the real-world crash benefits of safety technologies and recommends the approach for others to follow.

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In-vehicle filming of driver fatigue on YouTube: vlogs, crashes and bad advice

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Abstract

Background: Driver fatigue contributes to 15-30% of crashes, however it is difficult to objectively measure. Fatigue mitigation relies on driver self-moderation, placing great importance on the necessity for road safety campaigns to engage with their audience. Popular self-archiving website YouTube.com is a relatively unused source of public perceptions.
Method: A systematic YouTube.com search (videos uploaded 2/12/09 - 2/12/14) was conducted using driver fatigue related search terms. 442 relevant videos were identified. In-vehicle footage was separated for further analysis. Video reception was quantified in terms of number of views, likes, comments, dislikes and times duplicated. Qualitative analysis of comments was undertaken to identify key themes.
Results: 4.2% (n=107) of relevant uploaded videos contained in-vehicle footage. Three types of videos were identified: (1) dashcam footage (n=82); (2) speaking directly to the camera - vlogs (n=16); (3) passengers filming drivers (n=9). Two distinct types of comments emerged, those directly relating to driver fatigue and those more broadly about the video or its uploader. Driver fatigue comments included: attribution of behaviour cause, emotion experienced when watching the video and personal advice on staying awake while driving.
Discussion: In-vehicle footage related to driver fatigue is prevalent on YouTube.com and is actively engaged with by viewers. Comments were mixed in terms of criticism and sympathy for drivers. Willingness to share advice on staying awake suggests driver fatigue may be seen as a common yet controllable occurrence. This project provides new insight into driver fatigue perception, which may be considered by safety authorities when designing education campaigns.

Key words: social media, driver sleepiness, driver tiredness, driver drowsiness, driver behaviour, dashcam

Introduction

Fatigue has been promoted by the Queensland Police Service as one of the top ‘fatal five’ causes of crashes on Australian roads (Queensland Police, 2014). Fatigue is estimated to contribute to 15-30% of crashes (Connor et al., 2002; Williamson et al., 2011). Drivers who are fatigued have an increased risk of death or serious injury (Connor et al., 2002). While technology in the field of driver fatigue detection continues to improve, there is not currently any legally binding, standardised measure that could be used by drivers and police to measure fatigue (Radun & Radun, 2009). Instead, drivers need to self-monitor their fatigue levels and judge for themselves if they are fit to drive. It has been repeatedly observed that drivers are aware of feelings of fatigue e.g. (Filtness, Reyner, & Horne, 2012; Horne & Baulk, 2004; Williamson, Friswell, Olivier, & Grzebieta, 2014). Despite this, instances of self-reported fatigued driving are common (Radun, Radun, Wahde, Watling, & Kecklund, 2015; Vanlaar, Simpson, Mayhew, & Robertson, 2008; Watling, Armstrong, Smith, & Wilson, in press). The issue then must turn to why drivers continue to drive once they experience feelings of fatigue? An understanding of how driver fatigue is perceived by the general public is necessary to develop effective strategies to mitigate fatigued driving behaviour (Fletcher, McCulloch, Baulk, & Dawson, 2005).

Social media provides a platform for large amounts of information to be shared widely. The free video sharing website YouTube.com is one of the most popular social media websites, with approximately 1 billion users (YouTube, 2015). In particular young adults are the most likely age group to participate in video sharing (Lenhart, Madden, Smith, & Macgill, 2009) and are over represented in driver fatigue crashes (Horne & Reyner, 1995). As online video viewership continues to grow (Bondad-Brown, Rice, & Pearce, 2012), and considering that online activities have been shown to influence youth behaviour (Lewis, Watson, White, & Tay, 2007) this may become an effective medium for information dissemination by safety education campaigns. However, this potential benefit could be tempered by the sharing of information contrary to safety messages, either as part of the video content itself or in comments contributed by users. An understanding of the current content available online can be used to gain an insight into what representations of driver fatigue already exist in the community. Specifically, videos filmed by users (as opposed to commercial entities) inside their vehicles present a direct experience of driver fatigue. The authors recent content analysis of driver fatigue videos on YouTube.com identified that driver fatigue is most frequently portrayed as dangerous, however, those videos which trivialised the issue received more views and evoked more comments (Hawkins & Filtness, 2015). Additionally, it was noted that the 3rd to 6th most viewed driver fatigue videos were in-vehicle footage.

Previous research investigating public opinion of driver fatigue has shown that fatigued drivers are perceived as less culpable than drunk drivers in fatal crashes. Overall, drivers report greater awareness and concern about drink driving than driver fatigue (Vanlaar et al., 2008; Williams, Davies, Thiele, Davidson, & MacLean, 2012). Drivers also self-report using ineffective countermeasures to driver fatigue such as going for a walk, opening a window and listening to music about as frequently as using the effective countersue of drinking coffee, and considerably more often than pulling over and taking a nap (Anund, Kecklund, Peters, & Åkerstedt, 2008). However, there is inevitably some bias in such self-report findings because participants are directed to consider driver fatigue, whereas, in real life a driver must recognise fatigue and implement countermeasures under their own initiative. Through using YouTube.com data the current work adds a novel perspective to the understanding of perceptions of driver fatigue in a naturalistic setting, external to the priming effect which may be experienced using self-report surveys that artificially draw attention to the issue of driver fatigue.

Content analysis of YouTube.com footage is becoming of increasing interest to the public health field (Sampson et al., 2013). The video sharing website provides a unique opportunity to view naturalistic public perception of a public health issue on a large scale, without the need for directing participants' attention towards the issue of interest. To date, investigations into YouTube.com footage have included a range of public health topics, including vaccination, electronic cigarettes and alcohol intoxication (Ache & Wallace, 2008; Luo, Zheng, Zeng, & Leischow, 2014; Primack, Colditz, Pang, & Jackson, 2015).

The current study seeks to further previous YouTube.com driver fatigue content analysis (Hawkins and Filtness, 2015) by focusing on the perception of in-vehicle footage. User generated comments have previously been used to analyse public opinions and perceptions of health and political issues (Jaspal, Nerlich, & Koteyko, 2013; Regan et al., 2014). Analysing comments on these videos can provide insight into how the videos are perceived by others. The aim of the current study was to understand more about public perception of in-vehicle footage of driver fatigue. The objectives to achieve this were (1) quantify the reception to different types of in-vehicle driver fatigue footage, (2) use a thematic approach to identify the types of response videos evoked from viewers.

Method

Data collection

A search spanning five years (2nd December 2009 - 2nd December 2014) was conducted using the inbuilt YouTube.com search feature. Search terms used were: “sleepy driving”, “driving sleepy”, “tired driver”, “drowsy driver”, “falling asleep while driving”, “driver fatigue”, “sleeping driver”, “tired driving”, “driving tired”, “fatigue driving”, “drowsy driving”, “driving drowsy” and “sleepy driver”. These videos were the same as those analysed in Hawkins and Filtness (2015). All videos were watched. Those that predominantly featured footage filmed from the inside of a vehicle were extracted for analysis. Videos that featured no in-vehicle footage, only a brief portion of in-vehicle footage or footage produced professionally for films or advertisements that were produced in a highly artificial and controlled environment were not considered in-vehicle filming.

Data analysis

Video content

Each relevant video was watched by one researcher and assigned to a predetermined group. Either vlog (video blog) whereby the driver spoke directly to the camera; dashcam footage of poor driving and crashes happening outside the vehicle; or passengers filming drivers.

Reception

Reception was quantified by recording frequencies for comments, likes, dislikes, total views and mean views per day. Reception was compared by video content group. Duplications of the same video were included in analysis to get a complete picture of the reception.

Comment themes

The comments associated with each identified video were extracted for qualitative analysis. Data analysis was conducted using Nvivo software (version 10, QSR). Analysis included all text that was part of a comment typed by a user or in one instance automatically generated when the user took action (shared on Google+). Comments that were an exact copy of a directly previous comment were excluded due to the assumption that these were uploaded in error. Other text such as user names were not included in coding. Comments written in a language other than English were excluded.

The identified comments were inductively coded by one researcher without determining categories in advance. In assigning codes each individual comment was considered within the context of surrounding comments and the video it was posted to. Thematic analysis was used to classify comments into repeated concepts (Auerbach & Silverstein, 2003). Two researchers worked together to create broader categories by grouping common comment content themes.

Results and discussion

The initial YouTube.com search returned 559 videos. Videos were excluded if driver fatigue was not shown/discussed or was only briefly mentioned. In total 442 videos relevant to the topic of driver fatigue were considered. Of these, 107 (24%) predominantly featured in-vehicle footage, and were selected for further analysis. This sample consisted of 71 original videos and 36 duplicate videos.

Overall, dashcam footage was the most prevalent type of in-vehicle driver fatigue video. Table 1 shows the reception of videos by the type of in-vehicle footage. In terms of longevity, a video of dashcam footage has the most potential to create impact with the highest views per video per day. This is supported by the comparatively large numbers of likes, dislikes and comments they attract. These interactions suggest a high level of engagement with the viewer. It is concerning that 15% of these in-vehicle videos were drivers recording themselves speaking to camera while they were driving. Vlogging distracts the driver from their primary task which is particularly concerning when undertaken by a fatigued driver because tired drivers are more susceptible to distraction (Anderson & Horne, 2006). Mobile phone driver distraction research typically focuses on the driving implications of in-vehicle calls and texting e.g. (Gauld, Lewis, Haque, & Washington, 2015; Haque & Washington, 2013; Hosking, Young, & Regan, 2009), however, smart mobile phones have increased functionality including photo and video ability. Furthermore, a recent survey conducted by an Australian insurance provider reported that 14% of 18-24 year olds surveyed admitted taking a selfie while driving (AAMI, 2014). Future research should consider driver distraction implications of both vlogging and photo taking.

Table 1: Reception of in-vehicle videos

		Type of video		
		Dashcam n=82	vlog n=16	passenger filming n=9
# views	total	479887	293480	25751
	mean per video	5852.28	18342.50	2861.22
	range	2-194872	5-289297	4-14822
# views per day per video	mean per video	55.57	17.57	2.08
	range	0.01-4146.21	0.01-273.70	0.01-18.74
# likes	total	3381	46	111
	mean per video	41.23	2.88	12.33
	range	0-3088	0-18	0-99

	total	460	2	43
	mean per video	5.61	0.13	4.78
# dislikes	range	0-355	0-1	0-24
	total	1061	1267	77
	mean per video	12.94	79.19	8.56
#comments	range	0-659	0-1240	0-58

Comments

43 videos (40.2%) contained comments. Comments ranged widely in nature but two overarching themes were apparent. Distinction was made between (1) commenting directly on the issue of driver fatigue featured in the footage and (2) commenting on other aspects provoked from external factors such as video aesthetic quality.

On driver fatigue

Comments in this theme provide explicit insight into user's opinions of driver fatigue. These came in the form of situation specific and general judgements and opinions that are presented in Table 2. Four sub-categories of comment type were identified: relating directly to the events shown in the video, a response/experience of the viewer after having watched the video, speculation around future implications for the person(s) in the video and general discussion of driver fatigue.

Table 2 - Comments relating directly to fatigue in footage

Related to driver fatigue
Events shown
Attribution of behaviour cause
Sympathy for not at fault victim
Sympathetic of fatigued driver and/or acknowledgement of other causal factors
Critical of fatigued driver - they deserved to have a crash
Judgment (opinions) of the situation
Judgment of drivers
Recognition of bad situation
Sarcastic or joking
Attributing causes other than driver fatigue
Responses provoked by watching video
Emotion experienced when watching the video
Anger (unable to determine who directed to)
bad memories
concern
enjoyment of watching

fear
disappointed at negative outcome
shock
Sharing personal experiences
Future implications
Legal ramifications
Curious to know what happened after
General discussion about driver fatigue prompted by video content
Opinion of driver fatigue
Advice on staying awake while driving

Heated debate over who should be blamed for poor driving due to fatigue occurred in several situations. The most common defence of fatigued drivers was that other road users should have intervened to wake them up or where contributing to the crash by themselves driving poorly, e.g. a motorbike not being centred in the lane.

> 'If you don't at least try to act up upon things that are harmful to humanity, you will get your punishment...sooner or later. Thats a law. You don't just watch and "slow down cause you dont want to be involved" thats the reason why people die: Cause othe people didnt want to get involved [sic]'

Other comments of support for the fatigued driver minimised their responsibility without placing blame but simply that it was a mistake or accident. More concerning were comments that did not believe dangerous behaviour could be caused by fatigue and some attributed the cause most often to alcohol, drug use or medical problems instead. These sympathetic views are not surprising when looking at fatigue as a common and natural force that is safe and perhaps enjoyable in other circumstances of life (Nelson, 1997). Drivers often report experiencing driver fatigue on self-report surveys (Radun et al., 2015) so it is possible these commenters have a personal fatigue experience, prompting them to defend the actions of the driver in the video.

Equally emotive though, were responses criticising the fatigued driver. 'i [sic] would love to have some update on the white suv. i [sic] want him dead.' Punishment for fatigued drivers ranged from pragmatic legal aspects such as covering legal costs to vigilante style retaliation such as breaking off the side mirrors of drivers who swerved out of lane.

These responses highlight a need for more education around the realities of driving tired and ways that individuals can take personal responsibility for their safety. In particular, attitudes of shifted or shared responsibility with other parties when crashes occur may present a reason why some people continue to drive while tried. In addition, the contradiction and debate between comments indicates that public perception of driver fatigue is mixed. These strong and divided emotive responses should be taken into consideration when developing mitigation strategies and in deciding whether graphic imagery should be used. This is important because evoking a strong emotional response can be undesirable for conveying safety messages (Tay & Watson, 2002). Within the comments, there is a perception that driving tired is a mistake, therefore, public education campaigns may wish to consider focusing on communicating that driving tired can be avoided with proper planning and crashes can be prevented by pulling over to rest. Driver fatigue crashes are not unlucky mistakes.

Education may also be beneficial for correcting inaccurate beliefs about driver fatigue management. Safety messages are being accepted by some YouTube.com users. Accurate countermeasure suggestions included caffeinated food or beverages, pulling over, taking a nap and getting a lift with someone else instead. Such countermeasures have been demonstrated to be effective at reducing driver fatigue e.g. (Anund & Kecklund, 2011; Horne & Reyner, 1996). Other countermeasures were not as constructive. Loud music was often suggested as a means of staying awake. Music along with cold air have both been demonstrated as not effective at reducing driver fatigue (Anund et al., 2012; Reyner & Horne, 1998). Other suggestions were eating snacks, audio books, eating pepper or cinnamon, concentrating on getting home, cold air, chewing gum, singing, slapping yourself, being annoying to the driver (passengers) and sexual acts. These findings suggest fatigued drivers may continue to drive because they do not take driver fatigue seriously or see it as something that can be overcome by implementing countermeasures, naive to the reality that many may be ineffective. The presence of advice from unreliable sources in an online social setting has potential to normalise dangerous driving behaviour, especially as commenters spoke from firsthand experience. Further contributing to this normalisation may be vlog posts that explicitly state the driver is tired but do not enact any countermeasures or use the act of recording the vlog as a countermeasure itself. Vlogging is a fairly new concept and implications for driver distraction are not yet known.

On factors external to driver fatigue

Examining these comments gives insight into what external factors influence the way fatigue related in-vehicle footage is viewed, these concepts are presented in Table 3.Five sub-categories of comment type were identified.

Table 3: Factors external to driver fatigue

Not related to driver fatigue
Commenter centric
Off topic discussion
Promoting other videos
Opinions of other commenters
About the video itself
Should the footage exist?
Video editing/aesthetics
Shared on Google plus
Uploader promoting video
Inviting responses
Exclusive breaking news
Uploader directed comments
Speaking to uploader positively
Speaking to uploader negatively

All of the videos included in this analysis were about driver fatigue. However, not all viewer comments related to the video topic. The frequency of comments reflects engagement with the video content. If video sharing is to be considered as a way to promote the dangers of driver fatigue it would be desirable to enhance viewer interaction as much as possible. The volume of comments not related to driver fatigue demonstrates that features of a video itself are just as important as the content topic for engaging with viewers.

Videos featuring music were often commented on, asking what the song was or praising song selection. The low quality of video resolution and shot framing were also common points discussed. Many comments questioned whether footage was staged or real. Labelling a video as 'fake' appeared to be a way of dismissing its relevance. These aspects may play a role in distracting from the serious nature of a video's events or messages, particularly for crash footage. Alternatively, making creative use of these elements may serve to catch the attention of viewers and then incorporate strategies to follow up with meaningful educational messages. Poor quality footage is often not a barrier to a video's success on YouTube.com; eye catching, easily searchable titles and relevance to current affairs are better facilitators of high viewership (Grajales III, Sheps, Ho, Novak-Lauscher, & Eysenbach, 2014).

Many videos with high numbers of comments featured ongoing interactions in the comments section. The uploader of the video often contributed to this by writing replies to comments and posting comments themselves to generate discussion e.g. 'Would you pull over if someone kept honking at you?' This use of the comments section as a place for ongoing discussion demonstrates a level of engagement beyond making a one off comment and moving onto a new video, rather commenters do indeed read other comments. Although many conversations went off topic, they usually had a starting point that was sparked from watching the video. This is encouraging as it shows potential capacity for a dialog on driver fatigue to be well received within the online community, with the aid of facilitation.

Conclusion and directions for future research

It is essential that drivers take action to mitigate their own fatigue because driving when fatigued results in three times greater chance of a crash or near-miss than driving when alert (Klauer, Dingus, Neale, Sudweeks, & Ramsey, 2006). Understanding the public perception of this issue can provide insight to help inform future road safety strategies.

Driver fatigue does have an online presence on YouTube.com. A large portion of these videos are of in-vehicle filming, most commonly dashcam footage of crashes. The general public are strongly divided in opinion when commenting on these videos. While there is an indication that watching these videos is a source of entertainment many comments are emotionally laden and debate driver fatigue related issues.

A strength of YouTube.com video comments is that users can comment using a pseudonym. This anonymity may result in honest responses. However, this also presents the limitation that users may choose to post comments to be provocative or to present a curated image of themselves online. In these instances the user's offline opinions of driver fatigue may differ.

It is acknowledged that the current findings are limited by the proportion of videos that viewers provided comments on. Difficulty in interpreting comments that were short, poorly spelt or lacking context may have led to conservative estimation, notably comments coded as 'anger (unable to determine who directed to)' may have been directed at the driver being filmed. Additionally, the popularity of the video uploader, in terms of number of subscribers to a channel, was not considered as part of this study. Subscribers to an uploader's channel change over time as users subscribe and unsubscribe. It is not possible to obtain a record of the number of subscribers at the time of video upload. However, while subscribers may be more likely to view videos uploaded by a user they subscribe to, all videos analysed were public and could be viewed by any user regardless of whether they subscribed to the particular uploader or not. Future research may wish to consider uploaders' popularity (in terms of number of subscribers) and social influence. Understanding this influence could be useful as popular uploaders may be perceived as influential and may be capable of attracting higher video views. Future research could also investigate the link between dashcam, passenger filmed and vlog video opinions and actual driver behaviour. It is unknown if an entertaining and highly engaged with video can translate into better choices when drivers get behind the wheel.

This study contributes greater knowledge of not only what driver fatigue information and representations are generated and watched by the general public but also the existence of a dichotomy of opinion surrounding the issue. YouTube.com and other social networking platforms are a rich source of information which researchers can use to tangibly observe what captures the public's interest, as well as a potential source for information dissemination of safety strategies.

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Drink driving among Indigenous people in Far North Queensland and northern New South Wales: A summary of the qualitative findings

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Abstract

Purpose: In response to the threat that drink drivers pose to themselves and others, drink driving programs form an important part of a suite of countermeasures used in Australia and internationally. Unlike New Zealand/Aotearoa, United States and Canada that have programs catering for their First Peoples, all Australian programs are designed for the general driver population. The aim of this study was to identify the factors that contribute to Indigenous drink driving in order to inform appropriate recommendations related to developing a community-based program for Indigenous communities. Broader drivers licensing policy recommendations are also discussed.

Methods: A sample of 73 Indigenous people from Queensland and in New South Wales with one or more drink driving convictions completed a semi-structured interview in respect of the to their drink driving behaviour. Participants were asked to disclose information regarding their drink driving history, and alcohol and drug use. If participants self-reported no longer drink driving, they were probed about what factors had assisted them to avoid further offending.

Results: Key themes which emerged to maintain drink driving include motivations to drink and drive, and belief in the ability to manage the associated risks. Factors that appeared to support others from avoiding further offending include re-connecting with culture and family support.

Conclusions and Implications: A range of recommendations regarding delivery and content of a program for regional and remote communities as well as other policy implications are discussed.

Introduction

Drink driving has serious consequences for the health and wellbeing of Aboriginal and Torres Strait Islander communities in Australia (referred to as Indigenous people in this paper). Alcohol involvement has been identified as one of the main reasons Indigenous Australians are fatally and serious injured in road crashes (Boufous, Ivers, Martiniuk, Senserrick, & Stevenson, 2009). According to the latest figures, Indigenous road users are fatally-injured in road crashes at a rate 2.8 times higher than the general Australian population. Indigenous Australians also sustain serious injuries due to road crashes more often than other road users (30%) (Henley & Harrison, 2013), leaving many with serious disability or long-term conditions, such as acquired brain injury or spinal cord injury. Apart from the direct physical effects of road crashes, there are also the psychological effects, as families have to try and cope with the death or disability of a family member (Ferguson & Segre, 2012). The majority (70%) of approximately 450 fatal injuries per year in Australia and 60% of around 1600 serious injuries per year are suffered by Indigenous residents of ‘outer regional’, ‘remote’ and ‘very remote’ localities (Henley & Harrison, 2013), signifying targeted attention in these geographical areas is required to reduce the road-related health burden experienced by Indigenous Australians.

The majority of the penalties received by Indigenous drivers convicted of drink driving are based on deterrence theory (Homel, 1988). Studies have identified such penalties, including financial penalties and licence suspension, as having limited success in shifting attitudes and behaviour amongst Indigenous drink drivers. A loss of a drivers’ licence for Indigenous drink drivers often leads to further driving offences such as driving while disqualified. Consequently, the courts impose more severe punishments such as increased fines and/or imprisonment.

Various policy initiatives including the National Safety Strategy (ATC, 2011) have recognised the importance of improving the safe driving practices of Indigenous road users. Indigenous injury prevention is a relatively novel area, with commentators in Australia considering this to be because of the high social and physical health burden Indigenous Australians present (Ivers et al., 2008). There is limited literature available in Australia regarding the cultural, contextual or social underpinnings supporting Indigenous drink driving. Without this level of understanding it is difficult to design interventions that meet the realities and values of both the driver and community and reduce the contact Indigenous people have with police and the court system for drink driving. In response to the threat that drink drivers pose to themselves and others, drink driving programs also form part of a suite of countermeasures used in Australia and internationally.

Existing Countermeasures and Drink Driving Programs

A review of current Australian programs to address the problem of drink driving indicates that they are underpinned by values and contextual factors that meet the needs of mainstream non-indigenous drink drivers (see Table 1). All of these programs appear to be underpinned by the principles of deterrence theory (Homel, 1988) and include both punitive and educational components as a means to encourage participants to complete the program and become educated about the negative consequences of drink driving. It is envisaged that

Table 1. Overview of existing drink driving programs offered to Indigenous people in Australia, New Zealand, United States and Canada

	Under the Limit, QLD	Sober Driver Program, NSW	Drink Driver Education, NT	First Offender, San Juan, USA	One for the Road, New Zealand	Saskatchewan IDTC
Length	11 weeks	9 weeks; condensed version offered	1 week	28 days, residential	Session One (6 hours) Session Two (4 hours)	21 days, residential
Offender Type	Repeat	Repeat	First time and repeat	First time	Repeat	Repeat
Indigenous Audience	N/S	N/S	N/S	70%	30%	65%
Target Audience	Urban, Regional	Urban, Regional	Regional	Regional	Urban, Regional	Regional
Pre-Assessment	✘	✘	✘	✘	LDQ, AUDIT	ADS, DAST, AUDIT, IDTS
Theory	Stages of Change	Stages of Change	Stages of Change	CRA, Motivational Interviewing	Stages of Change	Social learning model of addiction; Stages of Change
Other Health Issues	✘	✘	✘	Health and nutrition Domestic violence HIV/AIDS prevention	✘	Diabetes, Gambling and Sexual Health workshops
Support provided post program	Completed as part of probation order	Completed as part of probation order	✘	3-12 month follow-up: weekly monitor meetings, AA meetings, vocational education.	Can be completed with probation order	Referred to probation or alcohol and drug counselling
Cultural Component	✘	✘	✘	Sweat Lodge; Talking circles	Inclusion of family attendance	Elder support; Sweat Lodge Ceremony

N/S – Not Stated; LDQ - Leeds Dependency Questionnaire; AUDIT- Alcohol Use Disorders Identification Test; DAST – Drug Abuse Screening Test; IDTS - Inventory of Drug-Taking Situations; CRA – Community Reinforcement Approach through a process of education and punishment, drink drivers will be deterred from future drink driving. Most of these mainstream Australian programs have been developed based on the meta-analysis of 215 evaluations of all types of drink driving programs by Wells-Parker, Bangert-Drowns, McMillen and Williams (1995). According to the authors of the study drink driving interventions including a combination of education, counselling and probation supervision were more effective than interventions that did not have all of these components (Wells et al., 1995).

The majority of the Australian programs are part of the sentencing process and completion in some cases is a mandatory requirement prior to re-licensing. Process and/or outcome evaluations have demonstrated that these types of programs can be both educationally beneficial and effective in reducing recidivism among the mainstream population of drink drivers (Dwyer & Bolton, 1998; Mills, Hodge, Johansson, & Conigrave, 2008; Mazurski, Withneachi, & Kelly, 2011; Siskind, Sheehan, Schonfeld, & Ferguson, 2001; Sheehan, Watson, Schonfeld, Wallace, & Patridge, 2005). Some programs such as the Queensland Under the Limit Drink Driving Rehabilitation Program (UTL) (Palk, Sheehan & Schonfeld, 2006) and the Victorian Drink Driver Education (Sheehan, Watson, Schonfeld, Wallace, & Patridge, 2005) program also assess for risky alcohol consumption and encourage participants to undertake more in-depth alcohol treatment where appropriate. However, none of the existing Australian programs consider the impact of alcohol on other health issues or take into account in a meaningful way the cultural context and factors that contribute towards drink driving among Indigenous people.

In an effort to treat Indigenous participants, program providers in the United States, Canada and New Zealand/Aotearoa recognise the value of including additional components dedicated to cultural values and traditions, and which include the principles of community re-integration, healing, inclusion of family in the program (Dawber & Dawber, 2013) and discussion with Elders and sharing circles (Woodall et al., 2007). The San Juan DWI program also takes an holistic approach towards the treatment of drink driving a by addresses alcohol use, abuse, and dependence, health and nutrition, psychological effects of alcohol abuse, drinking-and-driving awareness, stress management, goal-setting, family issues and alcohol, domestic violence and HIV/AIDS prevention. Program participants who are employed can continue with employment through a work release program. An evaluation of the program demonstrated that participants were less likely to be re-arrested compared to non-program drink drivers and after 5 years post program completion, treated drink drivers were 16.7% less likely to be re-arrested than non-treated drink drivers (Kunitz et al., 2002).

In view of the benefits that the San Juan DWI program has provided for America's Native American people and the limited culturally appropriate Australian Indigenous drink driving programs it timely to identify the most appropriate drink driving program content and delivery style for Indigenous drivers in Australia. The Centre for Accident Research and Road Safety – Queensland was funded by the National Drug Law Enforcement Research Fund to explore the psycho-social, cultural and contextual factors contributing towards Indigenous drink driving. The study aims to fill the current gaps in the literature to inform a treatment program and future policy measures to reduce drink driving. This project is specifically focused on Indigenous Australians in rural and remote communities as a large proportion of the injury-burden is experienced in non-urban areas (Henley & Harrison, 2013).

Methods and Materials

This project incorporates three independent but linked stages of quantitative and qualitative research designed to comprehensively investigate drink driving behaviour among Indigenous people in Queensland and Northern New South Wales. The paper will discuss a summary of the key findings from interviews with drink drivers. For more information in relation to the other stages of the project, the reader is referred to the full report (Fitts & Palk, 2015).

In stage 2, primarily qualitative methods are used to capture information about the drink driving histories of Indigenous drink drivers and the psycho-social, cultural and contextual factors that contributed towards their drink driving. Qualitative methods are a familiar and comfortable style for Indigenous peoples who feel included through talking and sharing, often referred to as 'research yarning' (Bessarb & Ng'andu, 2010). The research was conducted in Cairns Region and Cape York, Far North Queensland, and the Clarence Valley, Northern New South Wales. Indigenous persons familiar with the communities provided support to the research team to assist with liaison in the communities and identifying volunteer participants. Participants were recruited by word of mouth about the research project and the snowballing approach. This approach allowed for community members to become familiar with the aims of the project and to feel comfortable about the aims of the research and talk to the researcher. Participants for the project were provided from a number of community organisations including: the Indigenous justice group, health services as well as from key individuals in community groups (for example, the men's and women's groups). Approval to conduct this program of research was obtained from the QUT Human Research Ethics Committee and Queensland Corrective Service Research Committee.

A sample of 73 Indigenous drink drivers was identified (see Table 2), and following a discussion about the aims and requirements of the research consent for participation was obtained. Participants completed in-depth interviews, in respect of their drink driving behaviour, and an assessment of their level of alcohol consumption and cannabis use was also undertaken. In regards to participants who self-reported they no longer drive after drinking, participants were probed about the protective factors that assisted them to desist from further drink driving episodes.

Thematic analysis (Braun, 2006) of the interview transcripts was conducted by the first author using an interpretive framework. This began by reading through all transcripts and identifying broad patterns of experience that appeared across the interviews both in relation to the specific research interests, as well as other, unanticipated or emergent issues. These were labelled the themes. Material, in the form of sentences and/or paragraphs, were then coded manually into the themes, with multiple codes being used if the text fit into more than one theme. This was in order to ensure that data and meaning were not lost. To ensure validity, the independent analysis of the material was carried out by the co-author and another CARRSQ senior researcher experienced in qualitative analysis and the content of the themes. Subsequent discussion among the authors clarified minor points and allowed for agreement on the labelling of the themes. In addition, the first author sought input on the interpretation of the culturally related themes from two other sources: an Indigenous academic with knowledge of the issues relevant to Indigenous drink driving in regional and remote communities, and senior, respected community members from the study communities.

Table 2. Description of the participants

	Cape York, Queensland	Cairns, Queensland	Clarence Valley region, New South Wales
Gender			
Male	26 (90%)	17 (85%)	21 (87%)
Female	3 (10%)	3 (15%)	3 (13%)
Age groups			
>25	6 (21%)	4 (20%)	4 (17%)
26-39	14 (48%)	9 (45%)	14 (58%)
40+	9 (31%)	7 (35%)	6 (25%)
Highest level of education			
Year 7	0	1 (5%)	1 (4%)
Year 8	2 (7%)	1 (5%)	4 (17%)
Year 9	18 (62%)	14 (70%)	10 (42%)
Junior high school (year 10)	7 (24%)	1(5%)	6 (25%)
Senior high school (year 12)	2 (7%)	1(5%)	3 (12%)
Self-reported number of drink driving offences			
1 conviction	16(55%)	1	14 (58%)
More than 1conviciton	13 (45%)	19	10 (42%)
Other driving offences			
Unlicensed driving	11 (38%)	6 (30%)	8 (33%)
Theft of a vehicle	6 (21%)	4 (20%)	7 (29%)

Key findings

Below is a summary of the pertinent findings from the second phase of program of research.

- Participants reported a strong sense of 'family obligations' which referred to situations where they described pressure from members of their extended families to drive after drinking. The underlying responsibility for transporting family members appeared to be difficult to avoid and related to cultural values that involved responding to family needs as a priority.

  "There is a lot of pressure. You can't say no to family sometimes when people ask you to drive." (Man, age 30).

  Exclusion from peer or family networks was a common occurrence for participants who had refused family member demands. One respondent spoke about how she had been previously requested by her older sister to drink drive to purchase alcohol. She refused to drive her sister, which resulted in, "she [sister] didn't speak to me for weeks" (Woman, age 26). Emotional coercion by family members was also used to influence people to drink and drive.

- Some young participants were also motivated by a bravado mentality, referred to as 'being the hero' in the narratives. This involved situations where participants insisted in being the person who would take the risk of being caught by police for drink driving and hence protect other members of the group. These participants despite having, on some occasions, the opportunity to avoid drink driving (e.g. another person offering to drive) still insisted on 'being the hero' and taking the risk. Furthermore, in many cases, excerpts from the narratives of younger participants captured under this sub-theme talked about attempting to "show off" with an audience of peers while drink driving within the community only, and without an intended destination:

  "Lot of people, most boys, some boys find it [drink driving] funny. Yeah well that's what the young generation here now do. They thinkin' yeah "the people [are] watching me. I go fly through the street. There's a bunch of young girls watching us, you know?" That's what's the thinking [is] today, [they are] showing off, styling up, being hero." (Man, age 28)

- Participants were generally aware that drink driving increased the risk of being involved in a road crash and that it was dangerous. However, there was a perception amongst some drink drivers that the known risks could be managed through speed reduction and group decision making including nominating the person who was least intoxicated to drive. There appeared to be a belief that there are degrees of drunkenness and this corresponds to one's ability to drive the vehicle:

  "*Well whoever's going to pretty much sober. The other fella is drunk but not really, really drunk. He'll end up saying, "I'm more straighter than you two, I think it's best if I drive". But they're still in the risk anyway 'cause they're over the [legal] limit."* (Man, age 28).

- Some drink driver participants said the existing penalties were not generally a deterrent because they provided the offender with limited understanding of their offending behaviour or strategies to avoid offending it. Many of the participants also had a history of imprisonment.

  "Same with fines and jail. Most time guys don't learn why they are doing it." (Man, age 34).

  "I've been, I'm thirty, I've been in and out of jail through me twenties so it didn't really worry me." (Man, age 30)

- Several drink drivers reported learning to drive prior to the legal driving age. The youngest reported age was seven years. This was at a similar time when they were being exposed to drink driving during their childhood or adolescent years by older family members:

  "young, like thirteen [when I learnt to drive]. I worked at a wrecking yard in Newcastle, so I was driving cars around the wrecking yard from a young age....Um, always been around drinkers, yeah, and I yeah you could say that, yeah, around drink

driving yeah when I was young. I used to say it's not the license that drives the car." (Man, age 30)

One participant reported young children take on the driving responsibilities after their parents have been drinking: "*Where I'm from little kids they drive their parents' car around. When their parents are drinkin' and that."* (Man, age 36) Many participants felt that it was important to implement drink driving education awareness from school age.

- There were many drink driving who engaged in cannabis use before driving:

  "*The first car accident I had there. I be drunk and stoned too as well. I be coming around the corner and just lost control there."* (Man, age 38) Some considered that it was also important to include a drug driving component in the program: "*Gunja is also a problem. They should be taught about gunja and driving."* (Man, age 37)

- Most of the participants had been convicted of other driving-related offences including unlicensed driving and dangerous driving.

- Participants did not appear to understand what constituted a standard alcoholic beverage as defined by the Australian 'standard drink' guidelines. For participant who self-reported no longer drink driving, education regarding was considered to be important in understanding the effect drinking was having on their health and ability to drive safely:

  "Standard drinks was a real insight for me. I tried drinking standard drinks for a while there. Teach you about your health and what this substance does. I think to myself 'wow I been over pouring, not like standard drinks'." (Man, age 51)

- Re-connecting with family or developing new support systems was important for those drink drivers who were able to avoid relapse:

  "[We talk about] what you going to do, how you going to change, how you going to it again if you end up back in the same cycle. [We] have plans to achieve change. We do fishing, making spears, going out bush and all that and spending a day out there, We talk about alcohol and drugs, speed [amphetamines] and all that." (Man, age 33)

Discussion and Recommendations

The aim of the paper was to identify psycho-social, cultural and contextual factors from interviews with drink drivers to help develop program and broader policy recommendations for Indigenous regional and remote communities. Firstly, the findings suggest some of the program delivery styles and content already being utilised in programs for other Indigenous populations (Table 1) may be appropriate for Indigenous communities here. For example, the San Juan DWI and Saskatchewan-based programs recognise the value of cultural elements (sweat lodges, talking circles and ceremonies) and traditions in treating alcohol and drink driving (Woodall et al., 2007). Cultural participation through different avenues including the men groups were considered an important element to men in reducing both their alcohol use and further drink driving behaviour. Mens groups were originally designed to encourage and empower men to review and re-establish their roles in the family and in their communities. Equally important, these groups provide cultural elements whereby the role demands and rewards of other behaviours are rewarding beyond the realms of the social reinforcements that drinking provides.

Taking the findings reported here and existing literature together, recommendations regarding program content and related-licensing measures for regional and remote communities include:

- A community wide approach, with the inclusion of family, other community members in the program to change community perception and attitude towards drink driving,
- Comparable delivery style to that of the Saskatchewan (personal communication), and New Zealand-based (Dawber & Dawber, 2012) programs outlined in Table 1. Presence of community leaders and Elders in the facilitation of the program is recommended,
- Rather than capture drink drivers after re-offending (Mills et al., 2008), it recommended Indigenous drivers attend a program after their first drink driving conviction. Treatment in early in their trajectory may assist the treatment for the various psychological, lifestyle, cultural and contextual factors that maintain drink driving,
- Education on the impact of driving under the influence of alcohol, cannabis and other drugs, and prescription medication,
- Developing a relapse prevention plan for the drink driver that includes a support person to encourage safer driving and the strengthening of protective factors. The drink driver should also be encouraged to connect with other existing services such as the local men's/women's group and community-based drug and alcohol services,
- A mandatory component in which convicted drink drivers are ordered by the Court to participate in the program and attend the introductory day session and weekly sessions,
- The fee for Court mandated participation in the program should be similar to and in lieu of the fine they would receive for the drink driving conviction, and,
- Fees for voluntary non-convicted drinker's participation in the program to be waivered.

Consideration must be afforded to providing drink drivers the opportunity to re-apply for a learners permit upon successful completion of an extensive treatment program, particularly in the 'very remote' region, where a driver's licence is a necessary requirement for access into the workforce (Forrest, 2014). Alternatively, upon successful completion of the program Indigenous people living in remote communities could be granted a restricted licence to drive within the Indigenous community. This would reduce the incidents of arrests for unlicensed and/or driving while disqualified which often result in terms of imprisonment and over representation of Indigenous people, particularly in regional prisons.

Outside of a drink driving program, the findings of this study also indicate that there are other strategies required for reducing drink driving in regional and remote Indigenous communities including community-based initiatives to encourage parents to be active in their child's driving during the pre-licence period. During their formative years, participants here recalled being exposed to drink driving behaviour. Moreover, some participants reported children taking on the role of driving when their parents were intoxicated, possibly normalising illegal and dangerous driving practices. Parents have a pivotal role in their child's road behaviour as most young people will learn to drive through emulating their parents' behaviour, with little to no formal training or education available in regional and remote communities. Parents need to be aware of the considerable role they play in the road safety of young drivers, from being a model and source of driving attitudes, behaviours, rewards and punishments.

Lastly, future research should focus on the understanding the trajectory of drink driving among Indigenous youth, as well as exploring the extent of driving under the cannabis among Indigenous drivers.

A number of limitations in regards to this research are worth noting. For example, the current program of research was based on self-reports from a small sample of Indigenous residents convicted of drink driving from three regions and may not be transferable to other communities. Moreover, the sample consisted largely of male participants. While drink driving is predominantly an offence perpetuated by men, their opinions of the program may not apply to their female counterparts. Another limitation relates to language and cultural differences between the researcher and participants. In respect to the interviews conducted in Far North Queensland, English was sometimes not the language used at home. If the interviews had been conducted in a local dialect, this may have produced more in-depth responses. Although participants were asked if they would prefer to complete the interview in their local language with the assistance of an Elder to translate, all participants decided to complete the interview in English.

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The MUARC-TAC Enhanced Crash Investigation Study: A platform to understand the causes and consequences of serious injury crashes

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Abstract

Background: In recognising the consequences of serious injury crashes, the Transport Accident Commission (TAC) commissioned Monash University Accident Research Centre (MUARC) to undertake the Enhanced Crash Investigation Study (ECIS). This paper describes the program components, seven key research questions and technical innovations used in the study. We describe the information collected and outline a 'Safe Systems Failure Analysis' used for each case.

Project Method: Participants in ECIS include drivers aged 18 years and older seriously injured in crashes on public Victorian roads. Drivers are recruited whilst inpatients at a major trauma hospital and where possible interviews conducted. The ECIS team inspects their crashed vehicle and critically analyses the crash environment. Event Data Recorder (EDR, black-box) data is acquired from vehicles where possible and crash reconstructions are undertaken. Each case is submitted to an internal panel review with a sub-sample of cases presented to external panels throughout Victoria. This process leads to each case being submitted to a Safe Systems Failure Analysis where contributing factors and countermeasures are identified by a broad group of stakeholders. The ECIS control arm permits examination of the relationship between certain factors, such as speed and crash occurrence.

Results and Discussion: In addition to describing the study, we provide an example of how the identification of crash factors, using a Safe Systems paradigm based on real-world serious injury crashes, can lead to the identification of targeted countermeasures, each with an identified policy action.

Implications: This paper will demonstrate a method for creating a robust evidence base upon which government road safety policy can be built. By scaling up individual crash findings to the broader crash population, countermeasures and associated policy actions can be appropriately prioritised.

Background

Despite impressive, and well-documented, sustained reductions in the number of people killed on Victorian roads over the past two decades, the same reductions have not been observed in the number of people injured. Casualty crashes and their associated costs continue to represent a significant financial and public health cost to the Victorian community. Costs incurred by the TAC, Victoria's no-fault statutory insurer, amounted to $AUD1.01 billion in the 2013/14 financial year (FY) in the provision of care, income support and other items to persons impacted by road trauma.

At a person level, the TAC supported 47,115 claims, of which 22,012 were new claims in the 2013/14 FY; this represents an increase of 13.7% on the previous financial year (Transport Accident Commission, 2014). In the 12-month period ending July 2014, a total of 6,018 Victorian road users were hospitalised (27% of new claims; 40% drivers, 15% passengers), with 900 of these admitted for a period of greater than 2 weeks (15% of those hospitalised; 44% drivers, 18%

passengers) (Transport Accident Commission, 2015). Notably, claims involving hospitalisation increased by 15%, while the number of claims (persons) requiring hospitalisation for greater than 2 weeks was stable (-1%) compared to the previous 12-months. Modelling undertaken by MUARC indicates that if left unchecked the number of people injured will increase simply based on population increases alone (ECIS Study Investigators, 2013).

While the economic cost of road trauma is high, those injured also experience considerable negative impacts on their personal life. Research demonstrates on-going impairments in everyday functioning, as well as a range of consequences including difficulties returning to work, relationship difficulties, on-going pain and mental health difficulties that can persist for extended periods of time following road trauma (Fitzharris, Bowman, & Ludlow, 2010; Fitzharris, Fildes, Charlton, & Kossmann, 2007).

Given the unacceptable nature of losses and harms associated with road trauma, the Victorian Government has committed to a Safe System approach in striving to achieve the vision of zero road deaths and zero serious injuries. As a pathway to realising this vision, a target of achieving a 30% reduction in both deaths and serious injuries was set in Victoria's Road Safety Strategy 2013-2022 (State Government of Victoria, 2013). Recent work undertaken by the Victorian Government under the *Towards Zero* consultative process further emphasises the commitment in striving toward achieving zero road trauma.

With considerable emphasis being placed historically on reducing the number of road deaths, shifting this emphasis to also reduce the number of people seriously injured requires a new approach to understanding the causes of these crashes. Consequently, the Victorian Government, through the TAC, funded the establishment of the *MUARC-TAC Enhanced Crash Investigation Study (ECIS)*. The ECIS program was publicly launched in March 2014. The ECIS program aims to provide unprecedented insights into the causes and consequences of serious crashes, thereby supporting Victoria's efforts to implement the Safe System approach to road safety (OECD, 2008). It is expected that the comprehensive evidence generated through ECIS will help guide the Victorian Government's efforts to prevent crashes and reduce the cost of crash-related serious injuries.

This paper outlines the key elements of the ECIS program. In doing so, we describe the principal objective of the study and each component thereof. Further, we describe the conceptual approach adopted, program innovations, key questions, and demonstrate how the findings of the program will specifically inform Victoria's road safety policy and government road safety policy more generally.

The principal objective of the ECIS program is:

To determine the root causes of a representative sample of crashes and in 'scaling up' understand the determinants of high cost serious injury crashes.

To meet this objective, the study will take a 'bottom-up' rather than top-down approach by 'scaling up' 400 serious injury crashes, the goal of which is to inform the Victorian Government on how to implement Safe Systems thinking to best prevent these occurring in the first place. The ECIS program consists of multiple components, each complementing one another, thereby providing further insights to the relative importance of crash and injury risk factors.

Methods

ECIS program components

The ECIS program consists of five integrated components, these being:

1. Establishment of a 'state-of-art' knowledge bank of serious injury crash risk factors and known prevention measures;

2. Comprehensive analysis of TAC Claims data linked with crash data;
3. In-depth investigation of serious injury crashes;
4. Conduct of a 'control arm', hence creating a 'case:control' study, and
5. Examination of five pedestrian serious injury crashes as a feasibility exercise.

A brief description of the components is described in turn.

Component 1 – Knowledge bank

This component will take the form of a series of literature reviews focussed on key behavioural, vehicle and infrastructure-based crash and injury severity risk factors. The purpose is to contextualise findings from the ECIS program as well as providing a usable knowledge bank of known countermeasures and their effectiveness. Dissemination will take the form of web-based fact sheets, peer reviewed journal papers and institutional reports based on a specific topic, such as the contribution of driver age and fatigue in crashes for instance.

Component 2 – Analysis of TAC Claims data

The TAC holds comprehensive information on each client making a claim following involvement in a road crash, including crash details, injury details using ICD codes obtained from hospital records (WHO, 2005), health and ancillary services used, and costs associated with medical expenses and an array of other costs including, for example, lifetime care costs determined by actuaries. The TAC has linked this data to the Victoria Police crash reports and the VicRoads Road Crash Information System (RCIS). MUARC has enhanced this dataset in a number of ways, including the derivation of a range of injury metrics, including the Injury Severity Score (ISS) and injury severity codes (AAAM, 2005; Baker, O'Neill, Haddon, & Long, 1974). A description of this dataset and explanation of crash costs can be found in Buckis, Lenné and Fitzharris (In press). This dataset provides a rich source of information on all crashes that have occurred on public roads in Victoria since 2000.

A detailed analysis of this data will be undertaken as a means of documenting specific crash characteristics with detailed cost of injury data. In addition, the dataset will be used to establish 'sampling weights' that will be used in 'scaling up' the sample of 400 crash-involved drivers described in Component 3 (below). In this way, we will be able to describe in numeric and financial terms, the magnitude of various crash risk factors, such as speeding and forms of inattention.

Component 3 – In-depth investigation of serious injury crashes

The central component of the ECIS program is the in-depth investigation of 400 crashes, based on the recruitment of 400 drivers aged 18 years and older admitted to hospital following injuries sustained in a road crash. At present, the study is being conducted at The Alfred hospital, one of two adult major trauma centres in the State of Victoria. There are no exclusion criteria based on crash location, thus enabling drivers involved in crashes from across Victoria to be eligible for the study. Drivers excluded are those who cannot provide informed consent due to mental health or social welfare considerations or medical grounds, given the advice of the treating staff.

Figure 1 provides a schematic representation of the different elements of Component 3. As shown, the key steps are 1) an interview with the injured driver whilst they are an in-patient in hospital; 2) a detailed inspection of the vehicle(s), and 3) a detailed investigation of the crash scene. Table 1 provides an overview of the information collected for each of the 400 cases.

Table 1: Overview of data collected, using a Safe Systems paradigm

Driver (via interview)	*Vehicle*	*Environment*
• Circumstances leading up to crash, including trip purpose,	• Full vehicle inspection for damage, cabin intrusion,	• Comprehensive scene inspection, including

length, familiarity with route • Crash events and vehicle details, including seat belt use. • Pre-crash behaviours, including inattention. • Use of medications pre-crash & pre-existing health. • Drug and alcohol questions. • Sleep patterns. • Contributing factors, including passengers, other road users, infrastructure, vehicle failure. • Driving and crash history. • Validated psychological scales	roadworthiness, crashworthiness. • Damage profile measured, and measures of crash severity (km/h) determined per SAE standard with *Ai Damage* for crash severity. • Event Data Recorder (EDR): pre-crash speed, braking, accelerator position • Crash type coding.	measurement of road, skid marks, signage, speed zone, road surface, presence and construction of shoulder. • Classification of road based on VicRoads network. • Use of VicRoads *CrashStats* to establish site crash history.

Table 2: Supplementary data sources

Supplementary data sources
• Ambulance Victoria report, including transport times, treatment and conscious state using GCS; • Hospital medical records, including all injuries and treatment; coded using the AIS / ISS system; • Victoria Police crash report; • Photos from media coverage of crashes, and • VicRoads traffic count data for crash locations.

In cases where a driver is very severely injured, a relative / next-of-kin may be approached for purposes of informed consent and recruitment of the driver into the study. In these instances, no driver interview is undertaken. However, these cases remain extremely important given the severity of the crash and the resulting injuries. It is worth noting that a considerable amount of information can be gathered from the vehicle and scene inspection, as well as the supplementary data sources.

This component of the ECIS program follows broadly the processes adopted under previous in-depth crash investigation studies undertaken at MUARC. However, there are a number of innovations that distinguish ECIS from the earlier studies, including the technology used in crash reconstruction (i.e., HVE reconstruction software) and the inclusion of data from Event Data Recorders (EDR). These technologies, when used with in-depth data enable individual crashes to be reconstructed to estimate pre-crash speed and investigate the performance of the vehicle under a range of alternative scenarios, such as varied braking, reaction time and travel speed scenarios. It can, therefore, be systematically determined under what conditions that crashes may have been avoided or impact speed mitigated. An early example of this work is provided by Peiris et al. using ECIS cases where the effect of an earlier braking reaction time, improved road surface friction, and ‘Wipe Off 5’ (i.e., travelling 5km/h less) on crash outcome was examined (Peiris, Arundell, Gabler, Curry, & Fitzharris, 2015).

Of particular interest to the ECIS program is the influence of behavioural factors in crash causation. To this end, data collected includes a vast array of behavioural items. In addition to the open-ended and multiple choice items in the interview (see Table 1), the interview includes a number of validated health and psychological behaviour measures, including measures of general health and well-being (i.e., the SF-36), alcohol use (i.e., the World Health Organisation AUDIT), psychological health and distress (i.e., the Kessler K-10), driving behaviours using the Driver

Behaviour Questionnaire (DBQ), and a collection of three measures of 'sensation seeking', 'reward seeking' and 'impulsivity' (i.e., Zuckerman's 'Impulsive Sensation Seeking Scale; Barratt Impulsiveness Scale).

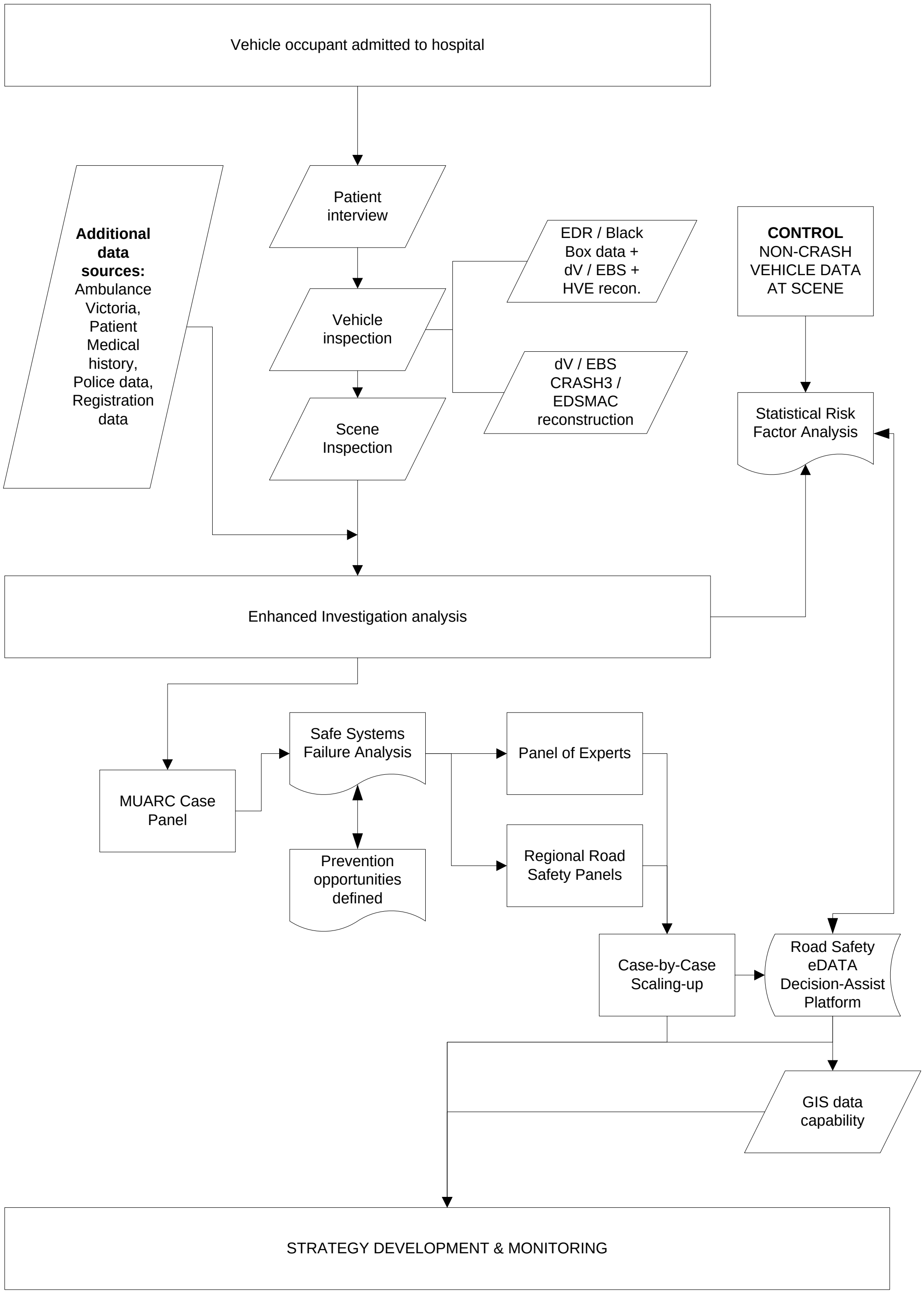

Figure 1: Representation of the MUARC-TAC Enhanced Crash Investigation Study

Analysis, use and interpretation of crashes – conceptual approach

The collected data for each of the 400 crashes are systematically analysed using an approach termed, *Safe Systems Failure Analysis*. The intent is to understand which elements of the 'system' aligned, or failed, such that the crash occurred. This is embedded in the principle of the Safe Systems philosophy whereby the key is to 'identify and rectify the major sources of error or design weakness that contribute to fatal and severe injury crashes, as well as to mitigate the severity and consequences of injury' (Peden et al., 2004: p.13).

For each crash, a *Safe Systems Failure Analysis* is undertaken within the project team, as well as when cases are presented at external expert panels. Throughout the process, contributing factors and evidence-based road safety policy options relevant for the whole network are identified. Each crash is individually examined with the Haddon matrix being used as the basis for the 'systems failure' analysis (Haddon Jr., 1968, 1972).

In examining each crash, key questions include:

1. What factors led to the crash?
2. What parts of the 'system' failed?
3. What parts of the 'system' were benign?
4. Was the crash potentially avoidable, the death preventable, or injuries able to be mitigated?
5. What factors are modifiable?
6. What can specific geographical regions learn from individual crashes that occur within their boundaries?
7. Scaling up, what policy options exist for the TAC and other road safety stakeholders in Victoria, based on the accumulated evidence, and known 'best practice' prevention, to prevent future 'like' crashes in Victoria?

In addition to the above, a '*Contributing Factors'* form developed specifically for use in the project is used by the MUARC ECIS study team to document all potential human, vehicle and environmental crash risk factors. Using this form, the investigation team note the occurrence or otherwise of each potential risk factor, and assign a confidence level, ranging from low, medium to high, that the factor contributed to the crash occurring or the severity of injuries sustained. The investigating team members (i.e., the Research Nurse and the Vehicle / Scene inspector) complete this form individually and are required to note the evidence source for each factor. This form is then reviewed by the broader ECIS team as part of an internal case review.

In total, included in the conduct of ECIS over a 3-year period are 12 city-based Expert Panels and 6 Regional Expert Panels. During these panels, cases are presented to a variety of experts from government, including police, road agencies, road safety bodies, ambulance and medical personnel, and local government officers. The principle objective is to gain further insights into countermeasure options from practitioners as well gain an increased understanding of the range of considerations impacting the implementation of road safety policy. The panels have a secondary benefit of highlighting the Safe Systems approach of road safety to a wide variety of Victorian stakeholders.

Recruitment response rates and sample characteristics: At the time of writing (end-August 2015), 146 drivers had been recruited into the study, representing 144 serious injury crashes, noting that both drivers from two separate crashes were enrolled in the study. Informed consent was obtained for each injured driver, with a relative / next-of-kin providing informed consent on behalf of six severely injured drivers.

Since recruitment commenced (11 August 2014), a total of 1,100 persons injured in road crashes were admitted to The Alfred hospital and screened for participation; of these 498 (45.2%; 61%

male) were drivers of passenger vehicles. Following study protocols regarding inclusion and exclusion criteria, as well as operational matters (i.e., nurse availability), 223 injured drivers were approached with the view of seeking their participation, representing 45% of all injured drivers admitted to The Alfred hospital. Of the remainder who were not approached (55%, n=275), 154 (31%) met study exclusion criteria (e.g., driver aged less than 18 years, medical grounds, psychological distress post-crash), 114 (23%) were discharged prior to being approached and 7 died in hospital (1%).

Of the 223 injured drivers approached, 146 consented to participation (60% male), 71 declined (56% male) and 6 patients were discharged prior to consent being gained (50% male). Hence, the response rate of those approached was 65.4%, the refusal rate was 31.8% and the percent lost due to discharge after approach but consent not being immediately received was 2.6%. The 146 consenting drivers represents 29.3% (i.e., n=498) of all drivers admitted to The Alfred hospital in the study period.

Sample representativeness is an important consideration, particularly in the ability of the study to make inferences to the broader serious injury crash problem. This relates to issues of participation and response bias. To this end, the sex and age distribution of all drivers admitted to The Alfred, as well as those recruited to ECIS and those declining participation was examined (Figure 2). By way of example, it can be seen that of all the drivers admitted to The Alfred hospital, 7% were females aged 18-25 years and 13% were same-aged males. Of the 146 drivers who agreed to participate in the study, 7% were 18 to 25 year-old females and 12% were 18 to 25 year-old males; of those that declined (n=71), 4% were 18 to 25 year-old females and 15% were 18 to 25 year-old males. While there are some small differences in the ECIS sample compared to all drivers admitted, chi-square analysis comparing the age/sex profile of participants vs. refusals and participants vs. all other drivers indicates these differences were not statistically significant (p>0.05).

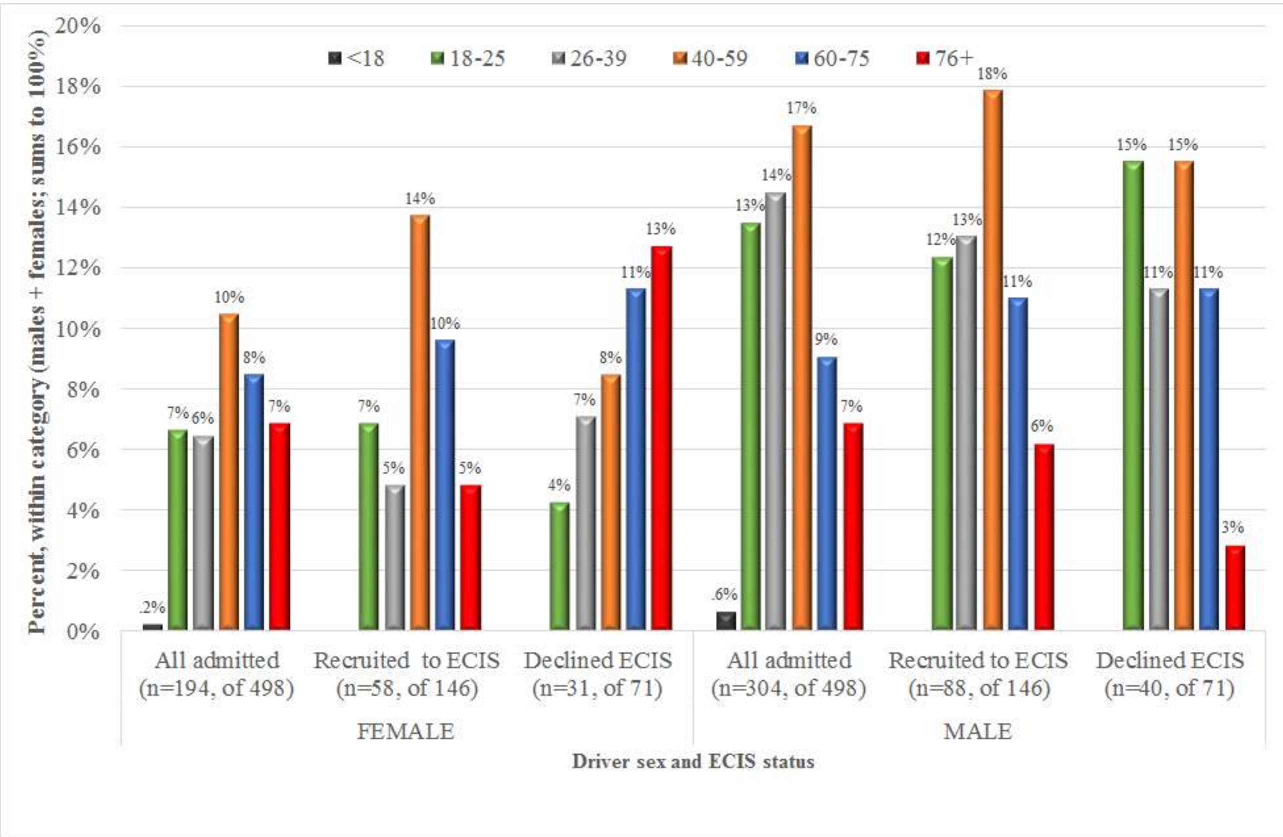

Figure 2: Sex and age profile of drivers admitted to The Alfred hospital, those recruited to ECIS and injured drivers declining participation

<u>*ECIS participant characteristics*</u>

Of the 146 drivers recruited to date, 19% were drivers aged 18-25 years (male: 64%), 17.8% were aged 26–39 (male 73%), 31% were aged 40–59 years (male: 56%), 20% were aged 60-75 years (male: 53%), and 11% were aged 76 years and older (56% male). The mean age of males was 45.6 years (*SD*=2.7; 95%CI: 40.1-51.1, Median: 43) and ranged from 18 – 86 years, while the mean age of females was 48.3 years (*SD*=3.2; 95%CI: 45.6-52.5, Median: 55) and ranged from 19 – 86 years of age.

Injury severity metrics - The mean length of stay did not differ across the five age groups shown in Figure 2 (mean: 9.3 days, 95%CI: 7.9-10.8; p>0.05) while the median was 7.5 days and 54% were hospitalised for 7 days or longer. Overall, half (52%) of the sample sustained a 'serious' (AIS3), 'severe' (AIS4) or 'critical' (AIS5) injury; this is referred to as an AIS3+ injury.

A higher proportion of drivers aged 18–25 years sustained an AIS3+ injury (70%), compared to all other age groups (26-39: 47%; 40-59: 38%; 60-75: 55%; 76+: 54%), although this difference was not statistically significant (p=0.3). Similarly, 70% of drivers aged 18-25 were classified as a 'major trauma' patient under the Victorian State Trauma Protocols (i.e., ISS >12), compared to between 42% and 55% of other age groups.

The higher severity of young driver crashes is seen in the mean Injury Severity Score (ISS) for the 18-25 year old group being 17.2 (SD=10.7, median: 15.5, range: 1-36) compared to the overall mean of the other age groups being 12.1 (SD=10.4, median: 9, range: 0-45) (p=0.053). Despite the injury severity among young drivers to be higher, the length of stay of 18-25 year old drivers (mean: 9.9 days, SD=8.8, median: 6.5, range 2-37) did not differ compared to drivers in all other age groups (mean: 9.2, SD=6.9, median: 8, range 1-27). Notably, fewer young drivers (40%) were discharged to a rehabilitation facility than older drivers (i.e., 60-75 years: 65%; 76+: 46%).

Vehicle age and crash type: The data also highlights a difference in the age of vehicles being driven at the time of the crash, with 75% of drivers aged 18-25 years driving a vehicle at least 10 years old, and half driving a vehicle more than 15 years old. In contrast, approximately 33% of drivers aged 60+ were driving vehicles aged 10 years or older, with one-third driving a vehicle of at least 10 years of age at the time of the crash; this difference was not however statistically significant. Only 5% of young drivers were driving a vehicle less than 3 years old. A higher proportion of young driver crashes were single vehicle crashes (SVC)(45%) compared to all other age groups, with the percent of SVC being 32% for 26-39 year old drivers, 31% for 40-59 year old drivers, 10% for 60-75 year old drivers and 15% for those over 76 years of age.

In short, based on the available data to date, young drivers – who represent 19% of those injured, are more likely to have been involved in single vehicle crashes, driving older vehicles, and were more severely injured than drivers aged 26 and older.

The data concerning sample demographics and injury severity are provided to give a general picture of the profile of drivers recruited to the study. While no robust conclusions can be drawn from this small sample, the differences in crash type and injury severity are notable, as is the similarity in the length of stay in hospital across age groups, despite differences in objective measures of injury severity. Future publications will focus on factors associated with crash risk, as well as further exploring the relationship between driver age, vehicle age, crash type and injury outcomes.

<u>*Consent to follow-up*</u>: Of significant interest is the pattern of recovery and health services used post-crash. To this end, 66% of the injured drivers have provided consent that enables future contact and follow-up to be made, 29% requested they not be contacted in the future, and 4% were next-of-kin consent cases where this is not appropriate. This data collection protocol is under development at the time of writing.

<u>*Ethics approvals*</u>

The ECIS case arm has been approved by the Monash University Human Research Ethics Committee (CF14/2329 - 2014001254) and The Alfred Hospital Human Research Ethics Committee (Approval: 249/14). These approvals dictate that individual case information be de-identified of all identifying details within four weeks of case recruitment, and that no identifying information be divulged to any party, organisation or person outside of the ECIS study team.

Component 4 - The 'control' arm (drivers not-involved in crashes)

The 'control' arm of the study aims to establish the profile of drivers that successfully pass through a crash (case) location; this is referred to as the 'study location'. The conduct of this component adds a 'case-control' element to the ECIS program. This permits estimates of risk to be determined for various factors, including for instance, vehicle speed, inattention, fatigue, and weather conditions. This is similar to studies previously conducted by Kloeden et al. who documented the crash risk associated with free travelling speed in urban and rural Adelaide (Kloeden, McLean, Moore, & Ponte, 1997a, 1997b; Kloeden, Ponte, & McLean, 2001). The ECIS study aims, however, to examine risk factors in addition to vehicle speed, alone, and in combination with one another.

Method: A control 'site' is that where an ECIS crash 'case' occurred (refer Component 3). In the one or two weeks following the crash, logistics permitting, a MUARC Technical Officer attends the crash site and using a LaserCam 4 (Kustom Signals, USA) covertly records the free speed of vehicles successfully passing through the crash site without experiencing a crash. Data is recorded for 30 minutes either side of the known crash time. Matching is undertaken only on day of week, time of day, and if possible, road conditions (i.e., wet / dry). For single vehicle crashes, only vehicles travelling in the direction of the 'case vehicle' are recorded, while for multiple-vehicle crashes (i.e., on-coming, intersection) vehicles from both directions are captured. Data captured includes vehicle speed, time of day, weather conditions, road conditions, vehicle manufacturer and model and vehicle registration. Traffic density is also collected, as well as details of all vehicles passing through the study location. As a way of providing a point of differentiation for drivers who pass through the location routinely, a large metal yellow sign is placed *after* the point of vehicle speed being recorded, stating "*You have passed through a Monash University study location".* A survey item (see below) specifically asks whether the driver has seen the sign.

Sampling and statistical power: Using the data collected, a paper-based survey is sent to 12 drivers travelling in each direction (if appropriate). Initially, surveys were sent to 30 drivers (in each direction) for the first 25 control cases; this was done to establish a representative response rate. Following this, the number of surveys sent was reduced to 12 based on an observed response rate of 25% and the recommendations for a 3:1 control:case ratio (Rothman & Greenland, 1998).

Survey procedure: Having captured vehicle details, the MUARC ECIS team then send to the TAC a pre-prepared survey pack, each with a unique code. This code is used by MUARC to link survey responses to the observed travel speed. MUARC supplies the TAC only with the vehicle registration number, who then sends the survey to the registered vehicle owner. The process is designed such that the registered owner receives the survey within 4-5 days of being recorded passing through the study site. The registered vehicle owner is provided a plain language statement and consent form while the survey provides a photo of the road where their vehicle was seen, ideally with no vehicle in view. The registered owner is asked to pass the survey to the driver of the vehicle at the stated day, time and location. A store voucher to the value of $50 is provided to drivers that return the survey within 2-weeks. The survey takes approximately 60–90 minutes to complete.

Survey materials: The 'control' survey is purposefully aligned with the 'case' questionnaire, minus questions relating to crash involvement. The survey contains items specific to driving through the location when observed, as well as questions relating to driving behaviour, speed choice, driving, crash and offence history, a detailed health profile, plus the validated survey instruments.

Early response rates: At the time of writing (end-August 2015), 60 'control' sites had been studied, with surveys sent to 1,785 drivers. Of these, 572 completed surveys have been received representing a response rate of 33%. A small percent of surveys (3%, n=52) were not sent by the TAC or were returned due to incorrect contact details; in such cases the registered owner had changed residence but had yet to update their address details in the licensing and registration system. Future work will provide an online option for completion of the survey and an assessment of the representativeness of survey respondents will be made.

Ethics approval

The ECIS control arm has been approved by the Monash University Human Research Ethics Committee (Control Arm CF14/1930 – 2014000983). This approval dictates the research comply with all relevant legislation concerning privacy, that survey responses be de-identified within 2 weeks of receipt by the ECIS team, and no identifying information be divulged to any party, organisation or person outside of the ECIS study team.

Component 5 – In-depth investigation of pedestrian crashes

This component seeks to examine five serious injury pedestrian crashes with a view to optimising future research opportunities and the expansion of the ECIS program into vulnerable road user groups. This component will involve the use of multiple data systems, including co-operation with Victoria Police amongst others. This component is presently under development but will involve similar methods and supplementary data used in Component 3.

Results - Early Insights

A key driver for the establishment of the ECIS program is to develop a comprehensive understanding of the full range of factors associated with serious injury crashes. This is done using a Safe Systems approach with a view of identifying a broad range of relevant and specific countermeasures and suitable policy actions for each crash. The establishment and conduct of city-based expert panels and regional expert panels is aimed at gaining insight from a range of different perspectives. To date, five city-based expert panels and two regional expert panels have been held; these involved the participation of 141 and 71 experts, practitioners and road safety stakeholders respectively, including visitors from Sweden and Africa. Panel participants represented local government, hospital-based medical staff, and all road safety agencies in Victoria. During these panels, a total of 21 ECIS crash cases have been presented, and for a select number vehicle speed data as measured through the control arm of the program was also presented. In reviewing these cases, the Expert Panels have made a number of high-level observations and have identified opportunities to implement innovative actions with the goal of reducing the number and severity of crashes, including the need to:

1. Manage vehicle speed where road and roadside infrastructure has not been designed to accommodate human error, that is, where infrastructure safety is of lower quality than the current speed limit might permit under a Safe Systems paradigm;
2. Build licensing, monitoring and infringement systems to monitor fitness to drive;
3. Examine innovative ways to control impaired driving;
4. Create and build systems and road infrastructure to manage non-compliant behaviour;
5. Create and build road infrastructure to accommodate a diverse range of human factors and errors, and
6. Mandate new vehicle safety standards and incentivise safe car selection.

These observations and recommendations have stemmed from the identification of factors associated with the crashes reviewed. Following the establishment of contributing factors, countermeasure options for each are identified and discussed, with each of these being translated into potential policy actions. As an example, Table 3 presents crash factors, countermeasures and policy actions that fall under the category of building a licensing, monitoring and infringement system that incorporates fitness to drive measures (see point 2 above). Further work is being undertaken to determine implementation issues and the likely effectiveness of these countermeasures and associated actions. This information is however presented here as an example of the approach being adopted in the ECIS program and the insights that can be gained. This process has been used in analysing each crash with the higher level categories noted above as 1-6 being established thus far, however these are not presented here due to space considerations.

Table 3: Crash factors, countermeasures and potential policy actions based on fitness-to-drive considerations seen in the reviewed ECIS cases

Contributing factor to crash	***Countermeasure***	***Potential policy action***

• Alcohol
• Drugs
• Abuse of prescription medications, alone and in combination with alcohol
• Emotional Stress
• Fatigue
• Human error
	• Alcohol interlocks
	• Drug interlocks
	• GP/Pharmacist advice on use on medication
	• Directly target drivers misusing prescription medication
	• Educate public on risks associated with:
	  o Impairing effects of alcohol
	  o Impairing effects of medications (& combinations)
	  o Fatigue / drowsy driving
	  o Emotional stress and driving
		• Mandatory alcohol interlocks, possibly using an incremental phase-in approach
		• Stimulate the development of drug interlock technologies
		• Link GP / Pharmacy / licensing databases to identify and contact high-risk drivers with a view to increasing their knowledge of impairment of certain medications.
		• Develop Fitness to Drive measures that determine when licensing should be reviewed and restricted based on risk profile
		• Raise public awareness of role of both mental health and fatigue on road safety

Discussion

This paper outlines the establishment of a comprehensive multi-component crash investigation system in Victoria, the goal of which is to provide the necessary understanding of the causes and consequences of serious injury crashes. The impetus for the establishment of the ECIS program was recognition that serious injury crashes carry considerable social, personal and financial cost to those involved as well as society more broadly. Given the TAC's role in providing care for those injured, including lifetime support, in addition to having a statutory responsibility for the prevention of road crashes, there is considerable investment in the ECIS program by the TAC.

The value of the ECIS program to the TAC and to the Victorian Road Safety Stakeholders will be in the insights it provides as to the underlying causes of serious injury crashes. More than that though, the ECIS program aims to offer definitive countermeasure solutions linked to cost-effective road safety policy. This program will provide the necessary evidence-base required for the establishment of innovative and perhaps challenging road safety strategies and action programs, an example of which can be seen in the direct links drawn between factors associated with real-world serious injury crashes, countermeasures and potential policy actions with respect to fitness-to-drive measures presented here. In using the Safe Systems approach, the full range of crash factors can be examined with highly specific and tailored countermeasures and innovative policy actions being identified.

The strength of the ECIS program is its multi-component nature, each of which provides a different but complementary insight into incidence, scale, underlying causes and outcomes of crashes. By adopting the latest innovations in data collection methods, and best practice science, the study will be well placed to deliver on its objectives. Despite the 400 crashes representing approximately 15% of all drivers admitted to hospital across Victoria, it is considered that the insights gained will be significant. It is also not considered feasible, practical or necessary to collect this type and amount of data on 100% of serious injury crashes; hence, a sampling approach supplemented by analysis of population-based road crash and claims data represents in our view, the most efficient way forward. Early analysis indicates that the ECIS sample is representative of the broader demographic of drivers involved in serious injury crashes, which is important in the context of 'scaling up' our insights to the broader crash problem.

A further strength is that the entire ECIS program is rooted firmly in the Safe Systems paradigm, a paradigm that underpins the new Victorian Road Safety Strategy, known as 'Towards Zero'. Indeed, the ECIS program covers the five road safety pillars enunciated in the *United Nations Global Plan for the Decade of Action for Road Safety 2011 – 2020,* these being:

1. Road Safety Management: target setting, data system establishment for defining, monitoring and evaluating road safety countermeasures;
2. Safer roads and mobility: to raise the inherent safety and protective quality of road networks for the benefit of all road users;
3. Safer vehicles: encourage universal deployment of improved vehicle safety technologies for passive and active safety through a combination of harmonisation of relevant global standards, consumer information and incentives to accelerate the uptake of new technologies;
4. Safer road users: develop comprehensive programs to improve road user behaviour focussed on key risk factors, and
5. Post-crash response: increase responsiveness to post-crash emergencies and improve the ability of the health and other systems to provide appropriate emergency treatment and longer-term rehabilitation for crash victims.

By design, the ECIS program engages with experts in each of these pillars, as evidenced by the Australian and International project team, and the composition of external panels. Further, the expert and regional panels offer an additional forum to seek the input of a wide variety of experts who provide invaluable insights into road crashes from a range of diverse backgrounds. A core output of the Panels is the formulation of an outcome document that lists contributing factors, countermeasure opportunities and their policy implications as seen here. The inclusion of the medical, legal and regulatory community is an important aspect of the study.

In addition to the contribution to future road safety programs, the ECIS program can play a broader educative role in the community. Through various channels, the findings of the ECIS program will be actively disseminated. This will be done with a view to align community attitudes on the importance of preventing serious injury road crashes with the importance of preventing fatal crashes.

Finally, the ECIS program will collect thousands of variables on each crash it investigates as well as on drivers passing successfully through locations where crashes have recently occurred. This method will provide new insights into a wide range of crash risk factors that have historically been difficult to quantify, such as distraction, fatigue and low level speeding. By examining each crash according to the developed 'Safe Systems Failure Analysis' paradigm, the ECIS team will be in a position to identify prevention opportunities in each element of the road transport system. The integration of findings from all of the study components will enable a complete picture of serious injury crashes to be achieved. From this, opportunities to prevent future crashes will be identified.

Limitations

The ECIS study acknowledges a number of limitations. The study is focussed on drivers of passenger vehicles, who are seen to account for 40% of all road users admitted to hospital, with passengers comprising an additional 15%. Hence, this study does not directly capture a large proportion of the serious injury crash problem, however, the insights gained may have application to other collision types that involve driver-to-pedestrian, driver-to-cyclist and driver-to-motorcyclist crashes. Given that the study aims to interview drivers injured in crashes, there may be instances where a passenger is injured but the driver is not; the extent of this and implications will be considered and documented as the ECIS study proceeds. There is also a need to examine crashes involving trucks, from the perspective of the truck driver, and indeed, a number of ECIS drivers were injured following collision with trucks. Expansion of the inclusion criteria to other road user groups is being examined, and this is important as the contributing factors, countermeasures and policy actions will likely differ depending on crash configuration and road users involved. The study also excludes drivers less than 18 years of age, principally for reasons of the practicality of gaining informed consent and also as they represent a small proportion of admitted patients as drivers (0.2%), as shown in Figure 2.

For multiple vehicle crashes, only one of the drivers is usually interviewed and their vehicle inspected. The one exception to this can be in the uncommon event of both drivers being i) injured, and ii) admitted to the recruiting hospital. For the two instances of 'driver pairs' being consented to the study, the Research Nurse team were unaware that both drivers were in the same crash until case processing commenced. While there would be added value in being able to interview both drivers involved in all recruited cases, assuming the other driver was not deceased, and conduct an inspection of both vehicles, this is not feasible for a number of reasons. Assuming the other driver is admitted to a hospital other than the current recruiting hospital, the ECIS study team would have to seek this information, as well as personal and health information, from a government agency, without that persons consent to do so. In such cases, the government agency would first have to contact that driver to seek permission to release details to the ECIS team. If it were possible to obtain this information and in the instance the other driver was admitted to hospital, the ECIS study would then require ethics approval in almost every hospital in the State so that there can be an assurance that the driver can be approached whilst in hospital; this is impractical for the purposes of the study due to time and resource limitations. It could also be expected that the response rate following this approach would be low, and it is probable that there may be bias in those drivers consenting for their details to be released to the ECIS team.

Following from above, the time to identify, contact, and consent the 'other' driver would be considerable–whether admitted to hospital or not–by which time it would be anticipated that memory of the crash event may have degraded, particularly given the nature of interview questions, and their vehicle likely repaired or destroyed. Further, depending on the extent of injuries sustained, and the capacity of the driver to consent, it may not be appropriate to seek contact with them directly, which would lead to contact with the next-of-kin; both of these have implications for ethics and privacy laws and release of personal information to the researchers. It is also considered that contact by telephone or letter be inappropriate due to potential for distress and harm, and ECIS protocols ensure that nursing and medical opinion is sought prior to approaching an injured driver.

While not directly seeking to interview both drivers of multiple vehicle crashes for the reasons noted above, it is considered that the protocols adopted by the ECIS study provide a robust basis for understanding the crash events and the role of both drivers with respect to pre-crash behaviours and any illegal driving behaviour on the part of both drivers involved.

Within both the ‘case’ and ‘control’ arm, sample representativeness and response bias are key considerations. As indicated, 65% of eligible injured drivers approached elected to participate in the study, and the age-sex profile of the ECIS driver sample is well matched to the broader injured sample, of which the ECIS drivers represent 29%. However, it is acknowledged that within each age-sex group, the reasons for declining participation might differ – including engaging in illegal behaviours such, for example, drink-driving, and this aspect needs to be monitored and reported upon. To date though, the sample includes drivers affected by alcohol and illicit drugs, as well as those who stated that they fell asleep whilst driving. Further work will examine this issue of potential bias and the impact on study findings. Sample representativeness of the case drivers will also be examined by reference to the analysis of the TAC Claims profile, which will include driver age and sex, crash type (i.e., single / multiple vehicle crash; crash type using the VicRoads Definition for Classifying Accident Code [DCA]; speed zone), impact object and, injury severity (i.e. length of stay, AIS severity) (see Component 2). Using these parameters, sampling weights derived from the analysis of the TAC Claims data will be used to ‘scale up or scale down’ cases so that they are collectively representative of the total serious injury crash problem in Victoria. A sampling procedure previously developed by Fitzharris et al. will be utilised here (Fitzharris, Scully, Fildes, & Gabler, 2005). This step will ensure insights gained from the ECIS serious injury cases will be appropriately weighted to reflect all serious injury crashes in Victoria.

Similarly, the response rate for the control arm has been shown to be 33%. Data is being collected on all vehicles that pass through the study site so that an assessment can be made of response bias based on vehicle speed and vehicle type and driver characteristics based on observation. Any bias is likely to impact on crash risk estimates calculated, and hence, this issue is being examined in detail.

A further limitation relevant to the ‘case’ arm is the inability, on a small number of occasions, to inspect the vehicle involved in the crash. This can occur in instances where the injured driver is not being the registered owner of the vehicle and the registered owner does not provide consent for the ECIS team to examine the vehicle, or the vehicle being sold and / or crush prior to the inspection being undertaken.

The ECIS study is not designed as an ‘on-the-spot’ study, with data collected retrospectively. The limitation of this is that the data at the scene of the crash may have degraded, however every effort is made to attend the crash scene within days of driver consent being granted. The use of multiple information sources, including photos obtained of the crash through media and other reporting mechanisms significantly enhances the understanding of the crash, and can overcome the deficiencies characteristic of retrospective crash investigation studies.

Finally, in the reconstruction of cases the simulation software (i.e., AI Damage, HVE) has a number of limitations relating to vehicle stiffness, which may influence estimates of crash severity and pre-crash speed, although a confidence range is also given. The study also aims to utilise EDR data, however not all vehicles in the study sample have these fitted, and not all can be downloaded at present due to proprietary technology reasons, thus limiting the number of cases for which objective recorded pre-crash driver behaviour is available.

Conclusion

This paper outlines the establishment and components of a comprehensive system for understanding the causes and consequences of a representative sample of serious injury crashes. Selected early insights have been presented. Using the *Safe System* as a conceptual basis for understanding the contributing factors for 400 serious injury crashes, and supported by a 'control arm', it is expected that the ECIS program will provide a new understanding of crash risk factors. As part of this process, a stated objective is to identify countermeasures and the associated policy implications for each observed risk factor. With the high number of serious injury crashes it is not feasible to study each in sufficient detail to conduct a comprehensive Safe Systems analysis. However, the use of sampling weights and an analysis of 10-years of TAC Claims data linked to crash data, the study will provide a strong platform for better understanding the determinants and relative importance of specific risk factors associated with serious injury crashes. In turn, this will permit an understanding of how reductions in high cost serious injury crashes to the TAC can be achieved. This understanding will further assist the TAC and those in the Victorian Road Safety Partnership (i.e., VicRoads, Department of Justice, Victoria Police, Department of Health and Human Services) to make highly targeted, and cost effective, decisions on how to best to prevent and mitigate serious injury crashes relevant to the whole State of Victoria. Collectively, the insights gained from all elements of the ECIS program will provide policy-makers the necessary tools to deliver a safer road transport system in Victoria.

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ECIS Study team

In addition to those named in the author by-line, the ECIS team consists of: Research Nurses: Sarah Bullen, Marnie Reilly, Emily Robertson, Karen Vlok; Technical Officers: Rai Curry, Robin Jackel, Lindsay Lorrain, Tandy Pok Arundell, Geoff Rayner; Data Coordinator: Debra Judd; Project Support Officer: Caitlin Bishop, Hayley McDonald.

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Criminal histories of crash and non-crash involved Queensland speeding offenders: Evidence supporting the idea that we drive as we live

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Abstract

Evidence increasingly suggests that our behaviour on the road mirrors our behaviour across other aspects of our life. The idea that we drive as we live, described by Tillman and Hobbs more than 65 years ago when examining off-road behaviours of taxi drivers (1949), is the focus of the current paper. As part of a larger study examining the impact of penalty changes on a large cohort of Queensland speeding offenders, criminal (lifetime) and crash history (10 year period) data for a sub-sample of 1000 offenders were obtained. Based on the 'drive as we live' maxim, it was hypothesised that crash-involved speeding offenders would be more likely to have a criminal history than non-crash involved offenders. Overall, only 30% of speeding offenders had a criminal history. However, crash-involved offenders were significantly more likely to have a criminal history (49.4%) than non-crash involved offenders (28.6%), supporting the hypothesis. Furthermore, those deemed 'most at fault' in a crash were the group most likely to have at least one criminal offence (52.2%). When compared to the non-crash involved offenders, those deemed 'not most at fault' in a crash were also more likely to have had at least one criminal offence (46.5%). Therefore, when compared to non-crash involved speeding offenders, those offenders involved in a crash were more likely to have been convicted of at least one criminal offence, irrespective of whether they were deemed 'most at fault' in that crash. Implications for traffic offender management and policing are discussed.

Introduction

A large body of road safety-related research has examined the links between a range of human factors (e.g., attitudes, motivations, personality traits) and on-road behaviours. Criminological research has also extensively examined links between such factors across a broad range of criminal behaviours. However, there has been relatively little work to date in the area where these two fields intersect – namely, the association between traffic offending, crash involvement and off-road criminal behaviour (Brace, Scully, Clark, & Oxley, 2010). Yet the idea that our on- and off-road behaviour would be consistent is not new. The idea that we drive as we live was first described by Tillman and Hobbs more than 65 years ago when examining off-road behaviours of taxi drivers (1949). They examined court and social services records of 96 crash-involved drivers and compared them to 100 non-crash involved drivers. Results indicated that 66% of the group with 4 or more crashes, compared to only 9% of the non-crash involved group, were known to at least one of the court/service agencies. From this finding they concluded that our personal life is reflected in our on-road behaviour ('a man drives as he lives', p.329); a concept that has also been described by others as cross-situational consistency of behaviour (Junger, West, & Timman, 2001). This maxim, that we drive as we live, is the focus of the current paper and is an area that has been noted as needing further exploration. As recommended by Brace et al (2010), ‘the relationship between crime and road safety, specifically, the link between criminal history and crash involvement, [should] be examined within the Australian context’ (p.37).

Relationship between on-road behaviour and criminal behaviour.

A growing body of evidence is suggesting that on-road behaviour mirrors behaviour across other aspects of life. For instance, work conducted in Britain sought to map associations between anti-social behaviours on the road with other criminal activity (Rose, 2000). Drivers were classified into three groups of serious traffic offenders: drink drivers, disqualified drivers, and dangerous drivers (including people convicted of speeding by excessive amounts). Comparisons with criminal history data revealed that a significant proportion of offenders from each of the three driver groups had mainstream criminal convictions (e.g., violence against the person, drug offences, robbery). Disqualified drivers showed the most involvement with other forms of crime, followed by dangerous drivers, and then drink drivers. The report’s summary highlights that serious traffic offenders should not be thought of in isolation from other criminals. Those convicted of drink driving, though reported as the group least likely to be involved in mainstream criminal activity, were approximately twice as likely as non-convicted drivers, to have a criminal history. These findings are consistent with work by Watson (2004) that found that almost 40% of the unlicensed drivers surveyed leaving court in Queensland, Australia, reported having a prior criminal conviction. Moreover, the proportion with a prior criminal conviction was particularly high (approximately two thirds) among the ‘disqualified’ and ‘never licensed’ drivers in Watson’s unlicensed sample.

Associations between self-reported lifetime traffic violations and self-reported lifetime illegal behaviours (including burglary, arson, assault, and disorderly conduct) have been examined among outpatients at a non-emergency medical centre in the USA (Sansone, Lam, & Wiederman, 2011). Results indicated a significant relationship ($r = 0.39$, $p < .001$) between the two types of behaviours, such that those drivers who reported more traffic citations also reported more illegal behaviours. When gender effects were examined, it was found that men reported statistically significantly more traffic infringements and other illegal acts. However, when looking at gender and history of traffic violations together to predict other illegal behaviours, traffic-related violations was the only significant predictor.

Similar research has been conducted in the Netherlands where a random sample of 1,000 crashes were extracted from more than 10,000 crashes registered in a police database in 1994 (Junger, West & Timman, 2001). The police records of 1,531 people found to be involved in those crashes were examined and were used to determine whether risky traffic behaviour had contributed to the crash. Results revealed that people who were recorded as demonstrating risky behaviour leading to a crash (e.g., speeding, tailgating, right of way violations) had an odds ratio of 2.6 for having a violent crime record, 2.5 for vandalism, 1.5 for property crime, and 5.3 for prior traffic crimes (e.g., refusing a blood test, hit and run, driving under the influence of alcohol). The authors concluded that these findings were indicative of a general underlying trait representing risk taking and/or lack of self-control.

Relationship between off-road behaviour and road trauma.

Another line of research enquiry has sought to investigate whether crime rates (including motor vehicle-related crimes) are specifically related to traffic fatalities and injuries. In relation to fatalities, for example, data across a broad range of variables from 28 European Union member states were obtained to examine the link between crime rates and traffic crash fatalities (Castillo-Manzano, Castro-Nuño, & Fageda, 2015). Results indicated that the overall criminal attitudes of a country were related to road crash fatality rates and further, that crimes more specifically linked to traffic violations (as measured by drug trafficking crime rates and motor vehicle theft rates) were statistically significant and positively related to road crash fatality rates. Overall, the authors concluded that across the 28 member states, the findings indicated that traffic fatality rates were higher in countries where people exhibited more ‘socially aggressive’ behaviour (as measured by overall crime rates).

Overall, the research summarised above represents an important line of enquiry; one that offers the potential to enable patterns of behaviour to be examined in order to help develop interventions that may be possible to prevent the pattern continuing. It is important to understand more about these patterns and to identify the factors that help to determine those at risk of crashing and causing harm to self and others. The current study contributes to this endeavour by examining links between road crash involvement and lifetime criminal offences among a group of speeding offenders. Speeding is, arguably, one of the more ‘socially acceptable’ driving behaviours, due in part to its transient nature and the widespread belief that everyone speeds (i.e., normalised on-road behaviour) (Johnston, Muir, & Howard, 2014). We have previously reported the relationship between speeding behaviour and criminal history for the sample used in the current paper, based on the categorisation of the sample according to an index speeding offence (once only low-range offenders, repeat high-range offenders, and other offenders) (see Watson, Watson, Siskind, Fleiter, & Soole, 2015 for a more detailed explanation of categorisation). Overall, results revealed significant differences in criminal offence histories, with repeat high-range speeding offenders more likely to have committed a previous criminal offence compared to the other two groups. More than half of this high-range speeding group (55.2%) had a criminal history (lifetime) compared to 21% of the other offender group and only 7% of the once only low-range group. The current paper extends upon these analyses to further examine patterns of behaviour by examining links between crash involvement and lifetime criminal history. More specifically, we were interested to examine the association between ‘at fault’ status in a crash and criminal history, since this area of enquiry has previously received limited attention. Research conducted in the United Kingdom sought primarily to examine the feasibility of linking policing and traffic authority licensing databases in order to investigate links between offending and crash causation (Dodson & Hill, 2010; Stannard, Cookson, & Hitchins, 2010). Offence histories for motorists from two areas (Nottinghamshire and Thames Valley) were examined and information on ‘at fault’ status of crash-involved motorists was obtained and matched across the two databases, where possible. The traffic authority licensing database contained information relating to causes and injury outcomes of all investigated crashes, whereas the police database contained conviction and arrest data for all non-motoring offences but also included motoring offences where there was some level of police involvement. It did not include minor traffic offences. Results revealed a clear link between ‘at fault’ status and offence history across both datasets. For instance, information contained in the licensing database showed that 40% of motorists deemed ‘predominantly at fault’ in a crash also had an offence history compared to 31% of those ‘not predominantly at fault’ – a statistically significant difference. Similarly, from records contained in the police database it was found that 28% of those deemed ‘predominantly at fault’ also had a policing offence, compared to 17% of those deemed to be ‘not predominantly at fault’ – a statistically significant difference.

Research hypotheses.

Based on the evidence presented above, it was hypothesised that crash-involved speeding offenders would be more likely to have a criminal history than non-crash involved offenders. In addition, it was hypothesised that those deemed ‘most at fault’ in a crash would be more likely to have a criminal history than those deemed ‘not most at fault’ in a crash, since this status may point to a level of risky driving leading to a crash.

Method

As part of a larger study examining the impact of penalty changes on a large cohort of Queensland speeding offenders, criminal and police-reported crash history data for a sub-sample of 1,000 offenders were obtained (see Watson et al., 2015 for further details). Criminal history was obtained from the Queensland Police Service and included all criminal offences committed by the sample of speeding offenders in their lifetime (up to the date of extraction, 20th April 2009). The criminal offences were categorised into offences against property (e.g., stealing, break and enter), offences against the person (e.g., assault), drug offences, traffic offences (e.g., drink driving, unlicensed driving, dangerous driving), offences against order (e.g., disorderly conduct, public nuisance), and regulation offences (e.g., gaming, prostitution, liquor licensing). For the purposes of determining the proportion of the sample with any criminal offence, traffic offences were excluded. Crash data was provided from the Queensland Road Crash Database by the Department of Transport and Main Roads. It included all police-reported crashes for the sample of speeding offenders between 1st January 1996 and 31st December 2005. ‘Most at fault’ status was determined based on an involved vehicle or person being deemed most at fault by police and designated a ‘Unit 1’ status. All other vehicles or persons were deemed to be ‘not most at fault’ (although may still have contributed to some extent to the crash).

Comparisons were made on the criminal histories, using chi-square tests of independence, between:

- non-crash-involved and crash-involved speeding offenders;
- ‘most at fault’ crash-involved and ‘not most at fault’ crash-involved speeding offenders; and
- non-crash involved and ‘not most at fault’ crash-involved speeding offenders.

Comparisons were also made for the type of criminal offence (i.e., property, person, drug, against order, regulation, and traffic). Phi (φ) was used as a measure of effect size with a value of less than .10 considered to be a small effect size, between .10 and .30 moderate, and more than .30 a large effect size (Aron & Aron, 1991).

Results

Of the 1,000 speeding offenders in the sample, 305 (30.5%) had committed a criminal offence some time prior to their index speeding offence and 89 (8.9%) were involved in a reported crash between 1st January 1996 and 31st December 2005.

There was a statistically significant difference between those motorists involved in crashes and those who were not in terms of their criminal histories [χ^2 (1) = 16.53, $p < .001$, φ = .13]. Specifically, a greater proportion of those involved in a crash had criminal histories compared to those who were not involved in a crash (Table 1).

Table 1: Criminal histories of crash involved and non-crash involved speeding offenders

		Criminal history[1]	
		No (%)	Yes (%)
Crash involved	No	650 (71.4)	261 (28.6)
	Yes	45 (50.6)	44 (49.4)

[1]excluding traffic offences

There was no statistically significant difference between those deemed ‘most at fault’ in a crash and those deemed ‘not most at fault’ in terms of the proportion with a criminal history [52.2% vs. 46.5%; χ^2 (1) = 0.29, $p = .593$, $\varphi_c = .05$]. Also, compared to those not involved in a crash a greater proportion of crash-involved motorists who were deemed ‘not most at fault’ had a criminal history (28.6% vs.46.5%) [χ^2 (1) = 6.31, $p = .012$, $\varphi_c = .08$] (Table 2).

Table 2: Criminal histories of crash-involved ‘most at fault’, crash-involved ‘not most at fault’, and non-crash involved speeding offenders

		Criminal history[1]	
		No (%)	Yes (%)
Crash involved	No	650 (71.4)	261 (28.6)
	Yes – most at fault	22 (47.8)	24 (52.2)
	Yes – not most at fault	23 (53.5)	20 (46.5)

[1]excluding traffic offences

Compared to those not involved in a crash, a greater proportion of crash-involved motorists had criminal offences recorded, for all categories of offence, a statistically significant difference in the case of property and regulatory offences (Table 3).

Table 3: Offence type of crash involved and non-crash involved speeding offenders

		Crash involved		
		No (%)	Yes (%)	Statistical significance
Property offence	No	780 (85.6)	131 (14.4)	χ^2 (1) = 17.69, p < .001, φ_c = .13
	Yes	61 (68.5)	28 (31.5)	
Drug offence	No	784 (86.1)	127 (13.9)	χ^2 (1) = 2.58, p = .108, φ_c = .05
	Yes	71 (79.8)	18 (20.2)	
Person offence	No	849 (93.2)	62 (6.8)	χ^2 (1) = 3.70, p = .055, φ_c = .06
	Yes	78 (87.6)	11 (12.4)	
Offences against order	No	822 (90.2)	89 (9.8)	χ^2 (1) = 2.07, p = .150, φ_c = .05
	Yes	76 (85.4)	13 (14.6)	
Regulation offence	No	873 (95.8)	38 (4.2)	χ^2 (1) = 4.29, p = .038, φ_c = .07
	Yes	81 (91.0)	8 (9.0)	
Traffic offence	No	848 (93.1)	63 (6.9)	χ^2 (1) = 1.24, p = .265, φ_c = .04
	Yes	80 (89.9)	9 (10.1)	

Discussion

To date, limited work has examined associations between on-road and off-road offending behaviour, particularly in the Australian context (Brace et al., 2010). However, the concept that people 'drive as they live' is not new. The current study sought to investigate links between lifetime criminal history and crash involvement among 1,000 speeding offenders in Queensland in order to add to the literature. Among that sample, 30.5% were found to have had committed a criminal offence at some point prior to their speeding index offence used in this study. We hypothesised that there would be an association between criminal history and crash involvement; there was mixed support for the hypotheses.

The first hypothesis, that crash-involved speeding offenders would be more likely to have a criminal history than non-crash involved offenders, was supported. We further hypothesised that 'at fault' status would be associated with criminal behaviour, since the limited evidence available had indicated that this outcome was likely (Dodson & Hill, 2010; Stannard, Cookson, & Hitchins, 2010). More specifically, we hypothesised that those deemed 'most at fault' in a crash would be more likely to have a criminal history than those deemed 'not most at fault', since this status may point to a level of risky driving/riding leading to a crash. This hypothesis was not strongly supported; the difference did not achieve statistical significance, although the direction of the result was in the hypothesised direction. This outcome may be due to the way in which fault is determined; an issue that is discussed further towards the end of this section, where study limitations are canvassed.

Implications for policing.

Finding support for our first hypothesis adds additional weight to the idea that 'we drive as we live'; that a pattern of behaviour off-road is continued on-road (whether because of a general propensity for risk taking, rule breaking, or other reasons; Junger et al., 2001). There are important implications of this finding in relation to policing because it is apparent that some traffic offenders are likely to be of great interest to police for reasons other than traffic infringements. As described by Rose (2000, p.68), 'the evidence shows that serious traffic offenders cannot be thought of as otherwise law-abiding members of the public'. This concept has important implications for policing and the manner in which scarce policing resources are allocated. With regard to this, some research has examined the impact of policing operations targeted at minor and disorder-related offences; an approach most well known as 'Broken Windows' policing (Kelling & Coles, 1996). The concept of 'Broken Windows' describes a situation where a determination to investigate and prosecute minor crime can lead to prevention of major crime. Specifically, it is suggested that if left unaddressed, these minor crimes may create an atmosphere of fear and contempt within a community that could indicate a lack of care and social control, thereby leading to the gradual deterioration of the community and providing an environment conducive to more serious offending (Kelling & Coles, 1996; Wagers, Sousa, & Kelling, 2008).

It has been argued that a similar concept applies in the traffic policing context. Giacopassi & Forde (2000) described the concept of 'Crumpled Fenders' which they identified as the traffic equivalent of 'Broken Windows'. It is the idea that limited presence of traffic law enforcement may portray the perception that police do not care about on-road offending and/or that they are unable or unwilling to enforce traffic laws. Giacopassi & Forde (2000) also suggested that limited traffic policing presence may enhance the perception that community norms in regard to policing are weak or non-existent. Of relevance to the current paper is the issue of ensuring that offenders (traffic or non-traffic) are detected and apprehended, and further, that policing resources are optimally used to promote community safety. From the information provided in the current paper, and from evidence reported elsewhere that indicates reduced crime overall as a result of traffic enforcement (for example, see Fell, 2013; Stuster, 2001), it is apparent that traffic policing has an extremely important role to play in enhancing the safety of the community (i.e., apprehending traffic offenders and non-traffic offenders) as well as in enhancing community perceptions about the level of overall policing being conducted. Use of police intelligence across policing activities is, no doubt, one important way that action can strengthen law enforcement efforts; a prime example of how ‘taking action together’ could improve road safety as well as community safety more generally.

Implications for offender management.

The findings reported in the current paper, supported by findings elsewhere, raise a critical question: *What can be done, if anything, to intervene with offenders in order to prevent the pattern of behaviour developing*? Indeed, this question is common among juvenile justice programs that seek to intervene to prevent recidivism by young offenders (Trotter, 2012). One response to that question is to continue to treat traffic offenders as ‘discrete entities’, such that any other misdemeanours they may have committed off-road are not considered when receiving traffic offence sanctions. Such an approach is underpinned by a lack of recognition that a person ‘drives as they live’ and by a focus only on on-road behaviour. This approach to offender management is potentially much less costly in a monetary sense in that it simply deals with offenders in one context via the application of one-off traffic-related sanctions each time an on-road offence is committed. However, compared to a more holistic approach involving aspects of diversion and rehabilitation, it is not necessarily more cost effective. It is, arguably, more cost effective to prevent further offending, including costs associated with injury and death from road trauma. Research conducted in Western Australia supports this idea (Ho, Rao, Burrell, & Weeramanthri, 2015).

Ho and colleagues (2015) sought to examine associations between on-road offences and road trauma and demonstrated a link between various risky/illegal on road behaviours and road related death and injury. In that study, researchers used clinical data from all adult road trauma patient admissions (n= 10,330 between 1998-2013) to the State’s Trauma Centre and linked them with previous traffic offences. They were attempting to assess whether traffic offence history could predict subsequent road trauma. Overall, 60.7% of admitted patients had prior traffic offences. Furthermore, the number of previous traffic offences was significantly associated with alcohol-related road trauma, severe trauma, and admission to an intensive care unit or death. The offences found to be most strongly associated with road trauma were drink driving, non-use of seatbelt, and using a hand-held electronic device. In support of the theme of the current paper, those authors concluded that road-related injuries did not simply happen by chance, but rather, were indicative of a pattern of risk-taking behaviours; a finding that will not be surprising to those who work in the road safety and policing professions.

Importantly, Ho and colleagues (2015) suggested that there are likely to be points for intervention, long before a person ends up as a long term offender with an extensive criminal and traffic offence history and a history of admissions to trauma services. They noted the possibility that a ‘window of opportunity’ exists to intervene in order to prevent a pattern of offending developing. We suggest that one avenue where this may occur is at the point of first contact with the justice system. As has previously been reported by Wilson and colleagues (2010) in relation to drink driving offenders, those who are termed ‘first offenders’ (i.e., making their first court appearance as a result of their first detection by police) should more accurately be termed ‘first time apprehended’, since many of the drink drivers in that particular sample reported previous drink driving episodes without being detected by police. Therefore, in their case, the first time that they came in contact with the criminal justice system (if it was indeed for that drink driving offence) indicates that a pattern of behaviour had already started to establish itself. The trial and evaluation of innovative interventions in order to determine whether a person’s first serious traffic infringement can be used as a successful point of intervention to prevent further offending seems entirely warranted. In addition, existing offender management approaches that involve some form of surveillance (e.g., alcohol ignition interlocks and intelligent speed adaptation devices) may serve to both constrain traffic offending as well as potentially deterring other types of vehicle-facilitated crime by creating the impression that one’s behaviour is constantly monitored.

Several limitations with the current research should be borne in mind when interpreting the findings presented above. Firstly, data used for the analyses reported above were primarily collected for administrative, rather than research purposes and may, therefore, be limited with regard to the level of specificity and sensitivity necessary for conducting scientifically rigorous research. Further, it is possible that errors occurred during recording and coding that can result in inaccurate or incomplete data. Additionally, the data relate specifically to motorists detected speeding in Queensland during specific time periods. We therefore recognise that it is not necessarily representative of all motorists, and further, that detections for speeding are unlikely to accurately reflect the prevalence of overall speeding because speed surveillance is not conducted across the entire road network at all times. Secondly, as noted earlier, the determination of fault in a crash can be problematic and has implications for our findings. As noted by Dodson and Hill (2010), ‘most at fault’ can be attributed to the person whose action/s directly precipitated the crash, irrespective of whether those actions were illegal. Furthermore, crash causation is complex and the attribution of fault can, therefore, occur at a simplistic level. The attribution of ‘most at fault’ in relation to our results, therefore, presumes that other crash-involved motorists (i.e., those deemed ‘not most at fault’) were not acting in the most inappropriate/ illegal/risky manner. However, it could be argued that those deemed ‘not most at fault’ in a crash may still have been driving in a risky manner, at a high risk time, or in high risk conditions, a scenario that may well be indicative of someone driving as they live, even though their ‘fault’ status would not reflect that.

Based on the findings reported herein, in conjunction with the work of others from a range of international jurisdictions, we are of the belief that on-road offending can act as a signal to police in regard to other offending behaviours. This is not to suggest that every single traffic offender should be offered a diversionary or rehabilitation program. Rather, we reiterate that there may be value in developing, trialling and evaluating intervention programs for traffic offenders that consider a broader focus than on-road behaviours (Ho et al., 2015). Conversely, there may equally be value in offering interventions to off-road offenders in association with probation that incorporate road safety messages.

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Helping Motorcyclists 'Ride to Live': developing a large-scale public education campaign for motorcyclists using research and stakeholder consultation

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Abstract

Motorcyclists are over-represented in NSW road trauma. Motorcycles represent only 3.6 per cent of motor vehicle registrations but account for 15 per cent all road fatalities and 11 per cent of all road injuries.

Research was undertaken in 2012 to understand the knowledge, attitudes and behaviours of NSW riders and drivers in relation to motorcycle safety. The research revealed that riders place a high degree of importance on skills and their own riding abilities, as well as externalise blame for crashes. A key challenge was to develop campaign messaging that was relevant and credible to riders without reinforcing stereotypes that suggest riders are non-compliant, risk-taking road users.

The 'Ride to Live' campaign was subsequently designed around acknowledging motorcyclists' passion for riding, whilst challenging riders to better manage their risks on the road. Campaign executions highlight common scenarios for commuter and recreational riders and illustrate the consequences of different choices riders can make in response to each hazard. It aims to encourage riders to make the safer choice – by anticipating the hazard and preparing early through good lane positioning, buffering and setting up brakes – without being too prescriptive and authoritarian. The campaign also encourages drivers to watch out for motorcycle riders.

Findings from the research were instrumental in developing an evidence-based campaign, along with strong collaboration with key stakeholder groups including NSW Motorcycle Alliance and Motorcycle Council of NSW. This extended to using important motorcycle networks to gain access to rider expertise and get a stronger campaign reach.

The need for a motorcycle campaign

Motorcycle riders are over represented in NSW road trauma, accounting for 15% of road fatalities and 11% of injuries while only making up 3.6% of registered vehicles in NSW.[i] Compared to drivers, motorcycle riders are at greater risk of fatality or injury as they are less protected in a crash. They have a fatality rate 23 times that of drivers (on a rate per kilometre travelled).

In the five year period from 2008-2012, there were 12,590 motorcycle crashes (including passengers) resulting in 297 motorcycle fatalities and 12,816 motorcycle injuries. Over the five year period, motorcycle casualties (injuries and fatalities) increased by 12%, three times more than all other road user casualties (4%).

Currently there are about 550,000 motorcycle licences in NSW (about 10% of all licences on issue) and about 200,000 registered motorcycles. However there is evidence of very strong growth in the number of motorcycle licences on issue.

In the five years since 2008, the number of motorcycle registrations grew by 28% compared to the number of passenger vehicle registrations which only grew by 9%. This increase in motorcycle registrations corresponds with the increase in motorcycle crashes. In future, there is the potential risk that motorcycle casualties may increase at a substantial rate, commensurate with registrations.

While the popularity of motorcycle riding is continuing to grow in NSW, saving motorcycle riders' lives and preventing injuries is becoming an increasingly critical road safety challenge for Transport for NSW.

The previous motorcycle rider campaign was 'Cornering' which encouraged riders to undertake safe riding techniques at corners and tight bends. While the 'Cornering' campaign was well received, the limitation of this campaign was that it only focussed on one element of the overall riding experience (particularly for recreational riders) and did not acknowledge the key risks for commuter motorcycle riders or the role of drivers in motorcycle crashes.

The role of the new motorcycle risk management campaign 'Ride to Live' is to encompass both motorcycle riders and drivers in the one campaign across a number of hazardous situations. This in turn will lead to better management of the risks contributing to motorcycle crashes.

NSW Motorcycle Safety Strategy

Motorcycle risk management is a key focus in NSW and actions and long-term initiatives to reduce the motorcycle road toll are articulated in the NSW Motorcycle Safety Strategy 2012-2021. The Strategy was developed by the NSW Centre for Road Safety along with the motorcycle community and key road safety stakeholders. Key actions include the development of targeted communication campaigns to address motorcycle crash risks through increased awareness of motorcycle safety and assisting riders to better manage risks on the road.

Stakeholder engagement has played an essential role in the development of the Strategy in terms of identifying and understanding the unique road safety risks for motorcycle riders and the need for a targeted safety improvement approach. Engaging with the motorcycle community, in particular the NSW Motorcycle Alliance and Motorcycle Council of NSW, has provided valuable insights into the specific risks and countermeasures that apply to motorcycle riding, due to different patterns of travel, environmental influences and the greater physical and cognitive demand required for riding compared to driving.

As part of the Motorcycle Safety Strategy, the Centre for Road Safety leads a Motorcycle Implementation Working Group with regular meetings to develop, implement, monitor and evaluate initiatives in the Strategy. The working group has also provided an important opportunity to discuss motorcycle risk management issues and consult with key motorcycle stakeholders throughout the development of this communications campaign.

The working group includes NSW Motorcycle Alliance, Motorcycle Council of NSW, Australian Motorcycle Council, NRMA Motoring and Services, NSW Police, Local, Government and Shires Association, Motor Accidents Authority, Roads and Maritime Services and Federal Chamber of Automotive Industries.

Evidence Gathering

NSW crash data analysis

Motorcycle riders can be divided into two groups based on the main purpose of their journey, commuter riding (for work or education) and recreational riding.

A commuter rider is a person who rides a motorcycle as a mode of transportation to and from their work or place of education during key commuter times. For the purposes of analysing crash data, this was defined as weekdays in the morning, 6am to 10am, and afternoon/evening, 3pm to 7pm. A recreational rider is a person who rides a motorcycle for enjoyment typically on the weekend.

An analysis of NSW crash data revealed distinct crash patterns for commuter and recreational motorcycle riders. Commuter riders are more commonly involved in lower speed crashes and crashes with other vehicles, particularly at intersections or in rear-end and lane change collisions. Recreational riders have a higher incidence of high speed, single vehicle crashes due to loss of control on both straight and curved roads.

The characteristics of the casualty crashes experienced by these two motorcycle groups are outlined in the following table.

Table 1. Characteristics of casualty crashes for commuter and recreational riders

	Commuter motorcycle riders (including scooter riders)	**Recreational motorcycle riders**
Where do motorcycle crashes occur in NSW?	• A higher number of casualties occur at intersections. • Over a third occur on 50km/h or 60km/h roads. • The majority of crashes occur on straight and dry roads.	• Over-represented in motorcycle fatalities in country areas. • Over-represented on 80km/h to 100km/h roads. • Over-represented on curved roads.
What time of the year do most crashes occur?	• There is little seasonal variation between when commuter motorcycle rider casualties occur. • However, there is a slight peak in commuter motorcycle rider casualties in Autumn and Spring.	• There is little seasonal variation between when recreational motorcycle rider casualties occur. • However, there is a slight peak in recreational motorcycle rider casualties in Autumn and Spring.
What time of the week and day do most crashes occur?	• Casualties peak in the evenings on weekdays from 5pm to 6pm.	• Casualties peak in the middle of the day on weekends from 11am to 3pm.
How do most crashes occur?	• The majority of commuter rider casualties involve multiple vehicle incidents, where the car was the key vehicle. • The most common crash types for multi-vehicle crashes are intersection crashes (turning crashes). • Multi-vehicle crashes at non-intersection locations are also common (rear-end/lane change collisions).	• A higher number of recreational rider casualties involve single vehicle incidents involving impact with a fence/safety barrier or animal. • In multi-vehicle crashes, the key vehicle is more likely to be the motorcycle.

Multi-vehicle crashes involving drivers and riders most commonly occur at intersections, particularly unsignalised T-intersections. They typically involve a vehicle turning from an adjacent or opposing direction into the path of an approaching motorcycle.

However crashes at non-intersection locations are also common such as when a vehicle collides with a motorcycle while changing lanes. These crash types suggest that the driver of the motor vehicle failed to detect the motorcycle rider or was in some way obstructed from detecting the motorcycle rider during these key manoeuvres. Key elements which may obscure driver vision and lead to crashes with motorcycle riders, both at intersections and when travelling in the same direction include:

- Motor vehicle blind spots
- Other vehicles
- Roadside objects
- Acceleration of motorcycle riders
- Motorcycles being smaller and more difficult to see in the traffic mix
- Motorcycle riders getting to the head of the queue.

Attitudes and behaviours of motorcycle riders and drivers

The issue of motorcycle risk management is complex in its nature. There are multiple target groups with differing behaviours and different attitudes towards the issue and each other. In 2012, quantitative research was undertaken to gain an in-depth understanding of the knowledge, attitudes and self-reported behaviours of NSW riders and drivers in relation to motorcycle safety.[ii] This consisted of an online survey of three groups: an online panel based sample of n=948 motorcycle riders and passengers weighted to reflect the population of NSW motorcycle licence holders; an open sample of n=1036 motorcycle riders sourced from a link placed on NSW motorcycle club and association websites; and a sample of n=997 drivers weighted to reflect the population of NSW driver licence holders.

The additional open sample helped ensure that the attitudes and behaviours of the active motorcycle riding population were captured. Research suggests that motorcycle licensing data over-estimates the number of active riders, in jurisdictions such as NSW where motorcycle licences are automatically renewed with the drivers licence even if the licence holder no longer rides a motorcycle.[iii]

Visibility and inattention were key concerns for both motorcycle riders and drivers. One fifth of drivers said that they have concerns about sharing the road with motorcyclists (21%). Drivers' concerns related to rider visibility and riding behaviour of motorcyclists. Drivers who have had a close call involving a motorcycle rider, and who attributed the close call to their own driving behaviour, stated the most common factor was they did not see the motorcycle rider (40%). This was most commonly due to heavy traffic, followed by poor visibility and weather conditions. Overall, many of the drivers surveyed gave responses which indicated that they have negative perceptions of motorcycle riders (61%) including concerns with riding behaviour such as weaving in and out of traffic and unpredictable manoeuvres of motorcycle riders. This was particularly evident among drivers under 50 years of age and those living in metropolitan areas.

Motorcyclists said that they were particularly concerned about their own visibility. Among motorcycle riders who had crashed, many attributed the cause of the crash to the inattention of the other road user (37%) and the other road user not seeing them (27%).

The common ground between drivers and motorcycle riders was that both groups thought that drivers and riders shared equal responsibility for the safety of motorcycle riders (73% of riders and 82% of drivers).

The research also highlighted key differences between the two motorcycle rider samples. Survey participants of the open sample (sourced through motorcycle club and association websites) were more likely to ride more frequently, report being involved in a crash or close call, and blame the other road user for the crash or close call. This group also had a much lower perception of risk and were more focussed on rider skills and the role of other motorists in crashes.

Riders in the open link sample were more concerned about the inattention of other drivers (43% vs. 32%) and were more likely to think that the driving behaviour of the other motorist was the main factor in motorcycle crashes (44% vs. 37%). While a greater proportion of the open link sample reported exceeding the speed limit every time or most times they rode (49% vs. 27%) these riders were less likely to think rider behaviour, such as speeding, was mainly to blame (16% vs. 28%). Where rider behaviour was involved, this group was more likely to think that motorcyclists' riding beyond their ability was the main factor (47% vs. 20%).

Table 2. Key differences between the two sample in terms of sample characteristics and attitudes and behaviours

	Open sample	**Panel ample**
Members of motorcycle clubs, groups or associations	43%	9%
Held a motorcycle licence	98%	71%
Owned a motorcycle	97%	62%
Rode most commonly as a rider (as opposed to a passenger)	99%	78%
Frequently rode on-road	90%	54%
Experienced a crash or close call with another vehicle(s)	30% and 82% respectively	23% and 53% respectively
Experienced a crash on their own	41%	32%
In terms of close calls, likeliness to blame another road user	78%	62%
Strongly disagreed that there's no such thing as safe speeding	27%	12%
Exceeded the speed limit every time or most times they rode	49%	27%

Following the results of the 2012 attitudinal research, segmentation analysis was also conducted in 2013 to identify whether there were any subgroups of motorcyclists who were at particular risk of being involved in crashes as a result of their risky riding behaviours.[iv] The analysis suggested a correlation between the number of years a motorcycle licence was held and reduced perception of risk. In other words, as a motorcycle rider's level of experience increases so too does their confidence in their riding ability, which in turn leads to a decrease in the perception of the risks of riding.

Campaign development

Campaign objectives

The overall communication objective for the motorcycle risk management campaign is to assist motorcycle riders and drivers to better manage risks that can lead to motorcycle crashes. A key challenge was to not only encompass motorcycle riders and drivers in the one campaign, but also to acknowledge the two distinct commuter and recreational rider groups and deliver messages which are contextually relevant to each one.

Target groups

There were two core target groups identified for the campaign - commuter motorcycle riders and recreational motorcycle riders.

Commuter rider casualties account for around 35% of all motorcycle casualties. While males in the 17-49 year age group account for 73% of all rider casualties, the 17-29 year age group are over-represented in commuter rider casualties. While scooter riders are a subset of the commuter rider group from a riding and crash pattern perspective, results from focus group testing revealed that scooter riders do not commonly identify themselves as motorcycle riders. Similarly, scooter riders are viewed as a distinct group by motorcycle riders, hence the need for targeted communications for this group.

Recreational rider casualties account for around 31% of all motorcycle casualties. While males in the 17-49 year age group account for 73% of all rider casualties, the 30-49 year age group make up the greatest number of recreational rider casualties.

The secondary target group is drivers, with a skew towards male drivers aged 17-54 years.

Campaign approach

The research evidence highlighted motorcycle riders' tendency to place a high degree of importance on skills and their own riding abilities, as well as externalise blame for crashes.

This posed a number of barriers and challenges which needed to be taken into account when communicating to this audience. Firstly, motorcycle riders are unlikely to accept communication materials which are perceived as reinforcing stereotypes that suggest they are non-compliant, risk-taking road users. This would have lead to resistance of the message. As a result, the challenge for the communication strategy was to communicate positive strategies which empower motorcycle riders to better manage their own risks on the road such as helping them identify potential hazards rather than dictating what riders should do.

Secondly, tackling a motorcycle rider’s decreasing perception of risk over time, as experience and confidence increases, was another challenge. However, by highlighting hazardous situations which all motorcycle riders face on the road, this reinforced the need to remain aware and mindful on the road at all times. Further, with the sense of freedom, passion and underlying pride most motorcycle riders enjoy, the communications did not limit or curtail this pay-off to avoid the message being rejected. Using a peer-to-peer tone of voice and partner style approach in communications assisted with this.

Lastly, as part of the overall motorcycle risk management issue, it was important to acknowledge both motorcycle rider and driver responsibility, without imparting blame on any one party. This would help to overcome some of the negative perceptions held by drivers and motorcycle riders towards one another and the tendency of both groups to externalise blame.

A strategic platform was developed to help inform the campaign so that it would resonate across the diverse target audiences and transcend the identified barriers and challenges to communicating motorcycle safety messages. The strategic platform identified the need to target self-efficacy or pride amongst riders and drivers and reduce their self-rated ability to perform a particular behaviour by illustrating and educating them on risk management skills. Simultaneously, there was also a need to change attitudes towards high risk interactions within and between target groups with the common goal of reducing motorcycle road trauma.

Creative development

Based on the insights gained from the research, the campaign was subsequently designed around highlighting common hazards that riders face on the road and illustrating the consequences of different choices riders can make in response to each hazard. The results of the crash data analysis were instrumental in informing the particular scenarios depicted in the campaign. For example, a vehicle turning into the path of an approaching motorcycle rider or a vehicle collision with a motorcycle while changing lanes is more common for commuter motorcycle riders. However for recreational motorcycle riders, losing control on a curved or straight road is more common.

Campaign executions include 30 second and 15 second television advertisements featuring metropolitan and rural locations to target the specific crash types and risk management strategies for commuter and recreational riders. The 30 second advertisements show a motorcycle rider approaching a hazard, and then splitting into three versions of itself. Each ‘clone’ rider takes a different approach in responding to the hazard – for example, one ‘clone’ rider makes the safer choice and successfully navigates through the hazard whereas the other two ‘clones’ make higher-risk choices and are unsuccessful in continuing their ride.

The campaign aims to challenge riders to better manage their risks by anticipating hazards and preparing early through good lane positioning, buffering and setting up brakes without being too prescriptive and authoritarian. A strong collaborative approach with NSW Motorcycle Alliance and Motorcycle Council of NSW was critical to ensure the campaign messages were relevant and credible to riders, and effectively addressed the unique road safety challenges for commuter and recreational rider groups.

When tested amongst the target audience, the focus group participants related to the ‘Ride to Live’ concept because it not only focused on hazards on the road, it also allowed motorcycle riders to think about how they would respond to the hazards in their own way.[v] This was a key objective of the campaign to empower motorcycle riders to identify and manage their own risks on the road. Further, the central proposition ‘Ride to Live’ was seen as an immediately identifiable positive road safety message which celebrates the joy of riding, while reminding motorcycle riders that, whatever the reason they choose to ride, they should draw on all their knowledge and experience to always ride at the best of their ability (see Figure 1).

Figure 1. Campaign creatives – recreational rider and commuter rider execution

The ‘Ride to Live’ creative received a good response from drivers as well, with the feedback in line with that of motorcycle riders. Drivers understood the hazards and their role in improving the safety of motorcycle riders even though it was talking to motorcycle riders directly.

A tailored driver execution was also developed to challenge drivers to think about how closely they look for motorcyclists and to remind drivers to check blind spots and look out for motorcyclists at all times. It links to the rider creative through the tagline ‘help motorcyclists ride to live’ which is relevant to them (see Figure 2).

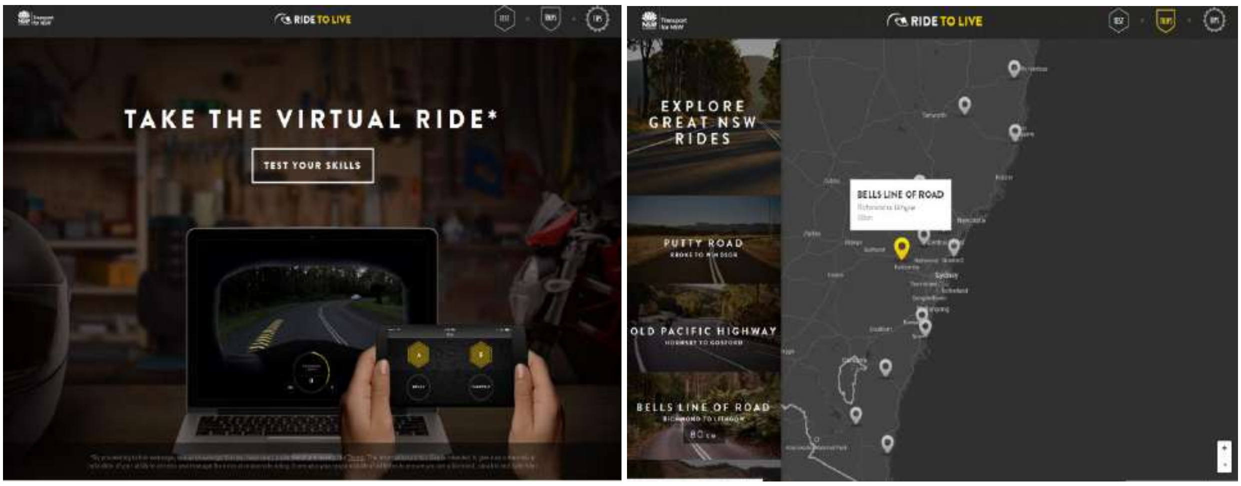
Figure 2. Campaign creative – driver execution

As scooter riders view themselves differently from motorcycle riders, a separate creative execution was developed for this audience.

In addition, outdoor billboards play an important role in reaching riders and drivers on the road at the point of behaviours, where they are making decisions and preparing for hazards. The billboards are strategically placed at key locations based on: rider registration data, crash data, NRMA red flagged road surveys, Roy Morgan Data, popular motorcycle routes, previous motorcycle campaigns and motorcycle parking locations.

The television campaign is fully integrated and supported with a website (ridetolive.com.au), which includes online hazard tests based on key crash types for commuter and recreational riders (using real footage), safety tips, and a trip planner of popular recreational riding routes in NSW featuring hazard information, recent crashes, weather, traffic and places to stop (see Figure 2). This provides a strong call to action, particularly to drive riders to the digital and social environment to access further information on hazards and risk management strategies, which is a significant element of the campaign.

Figure 2. Extracts from ridetolive.com.au



Stakeholder consultation

Extensive stakeholder consultation was used to inform the development of the new 'Ride to Live' campaign. The two key stakeholders involved were the NSW Motorcycle Alliance and Motorcycle Council of NSW. Both organisations represent the needs of motorcycle riders across the state and were involved in all phases of the campaign development, from the concept stage through to filming and production. A motorcycle rider trainer was also engaged during the filming process to ensure that the riding techniques used by the motorcycle riders in the campaign were accurate and safe. These relationships enabled stakeholder channels to be leveraged ensuring effective promotion, support and credibility of the campaign within the motorcycle community.

NSW Motorcycle Alliance, Motorcycle Council of NSW and NSW Police Force were also involved in promoting the ‘Ride to Live’ message through their own existing communication channels.

Campaign success

The campaign launched in November 2014. This enabled the new ‘Ride to Live’ messaging to be established and allow awareness of the campaign to build over the peak recreational riding season.

Online surveys were conducted before and after the campaign launch, with key findings relating to riders including:[vi]

- Recognition of the campaign was very high across all media channels. Almost 75% of motorcycle riders in the post-wave recalled at least one element of the campaign. TV, outdoor and radio channels were seen by around 1 in 2 riders.
- 70% of commuter riders thought the 30 second commuter TVC and 79% of recreational riders thought the 30 second recreational TVC communicated to them the need to be aware of potential hazards on the road when riding.
- 63% of commuter riders and 67% of recreational riders thought the relevant 30 second TVC made them think about the consequences of different choices motorcyclists can make when riding.
- Message take-out was strong and successfully related to hazard perceptions. While there were various interpretations of the hazards message because of the various scenarios depicted across the TVCs, overall the campaign successfully communicated the need to be aware of / prepare for hazards.
- 80-90+% of riders already self-report riding in a safe manner, for example slowing down on corners, leaving a safe braking distance and scanning the road for potential hazards. As such, achieving an observable change in behaviour is difficult. At this early stage, there were few observed campaign effects in the current behaviour of riders between the pre and post waves.
- The campaign appeared to have increased the likelihood of riders starting corners wide, particularly amongst recreational riders, from 43% pre wave to 57% post wave.

Key findings relating to drivers included:

- Overall the campaign achieved strong levels of recall amongst drivers, but the rider targeted executions were also highly visible to drivers.

- There was strong agreement among drivers that the driver execution communicated the need for drivers to 'look for motorcyclists' (67%) and for drivers to 'be aware of the risks they pose to motorcyclists' when driving (54%).
- When looking at change in behaviour due to campaign exposure, those exposed to the campaign indicated that they specifically looked out for motorcyclists on the roads around them compared to those who were not exposed to the campaign.

Ongoing campaign tracking throughout the year will continue to provide insights on how the campaign is performing and help inform any changes to the campaign.

In addition, the response to ridetolive.com.au has been extremely positive. Since its launch in October 2014, there have been more than 93,000 users, spending an average of over 3 minutes on the site (as at 23 June 2015). Visits to the website have been slightly higher amongst commuter riders than recreational riders (20% vs 10%) and those who visited the website were also very likely to take the online hazard test. Almost 65,000 tests have been completed (as at 23 June 2015), sharing the benefit of providing relevant and useful information in an interactive and engaging format.

Further evolution of the campaign will be considered in the future to ensure continued awareness, relevance and effectiveness for riders in the target audience. Transport for NSW is also working with the motorcycle community and key stakeholders to develop the next three years of actions within the Motorcycle Safety Strategy, which will include enhancements to the 'Ride to Live' website.

Summary

The 'Ride to Live' campaign is the first integrated motorcycle education campaign in NSW. It targets both riders and drivers through television, outdoor, digital and radio advertising. The campaign aims to highlight scenarios which put motorcyclists at risk, and encourage riders to make safe decisions in order to manage their risks on the road. It also promotes safer interactions between drivers and motorcycle riders by alerting drivers to the risks they pose to riders.

The results of the crash data analysis and quantitative research were instrumental in the development of the new campaign, and were considered at every stage to ensure the campaign messages were relevant and credible to riders, and effectively addressed their unique road safety challenges. This was also achieved through a strong collaborative approach between teams within Transport for NSW and key motorcycle stakeholders including Motorcycle Alliance and Motorcycle Council of NSW.

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Security Issues for Future Intelligent Transport Systems

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Abstract

Cooperative Intelligent Transportation Systems (C-ITS) allow in-vehicle systems, and ultimately the driver, to enhance their awareness of their surroundings by enabling communication between vehicles and road infrastructure. C-ITS are widely considered as the next major step in driving assistance systems, aiming at increasing safety, comfort and mobility for drivers. However, any communicating systems are subjected to security threats. A key component for providing secure communications at a large scale is a Public Key Infrastructure (PKI). Due to the safety-critical nature of Vehicle-to-Vehicle (V2V) communications, a C-ITS PKI has functional, performance and scalability requirements that differ from traditional non-automotive environments. This paper identifies and defines the key functional and security requirements for C-ITS PKI systems and analyses proposed C-ITS PKI standards against these requirements. In particular, the proposed US and European C-ITS PKI systems are identified as being too complex and not scalable. The paper also highlights various privacy, security and scalability concerns that should be considered for a secure C-ITS PKI solution in the Australian transport landscape.

Introduction

Connected systems and (semi) autonomous vehicles will be the hallmark of the future generation of Intelligent Transport Systems (ITS). In the US, assuming a full market penetration, connected vehicle safety applications could potentially prevent 25,000 to 592,000 crashes, save 49 to 1,083 lives, avoid 11,000 to 270,000 Maximum Abbreviated Injury Scale (MAIS) 1-5 injuries, and reduce 31,000 to 728,000 property-damage-only crashes annually (Harding et al., 2014). Vehicles' safety and mobility functionalities are increasingly reliant on software and wireless communications. Dedicated Short Range Communication (DSRC) is predicted to be the defacto standard supporting inter-vehicular communications. Vehicle-to-Vehicle (V2V) equipment and supporting communications functions could cost approximately US$341 to US$350 per vehicle in 2020 (Harding et al., 2014). The future environment of C-ITS will be characterised by highly mobile cars, a dynamic network topology with extremely short connections, variable network reliability and lower computing power relative to the desktop counterpart. The pervasiveness of DSRC will make on-board safety software vulnerable to cyber attacks.

To protect V2V communications, particularly safety critical messages, authentication is required. The Internet uses public key cryptography and digital signatures to provide authentication. Public key cryptography requires that each entity has a private key that is only known to the owner of the key and a public key that is distributed to all message receivers. A message sent to the receiver also contains a digital signature of the message and a certificate that contains the public key of the sender. Figure 1 depicts the process of signing and verifying messages using public key cryptography. The sender’s public key is used to verify messages that can only be created by the sender’s private key. The problem is that if a public key is incorrectly labelled, then the receiver can verify a message and mistakenly think an invalid message is correct. A PKI contains a distributed system of certificate authorities. The Certificate Authority (CA) in a PKI as shown in Figure 1 distributes and vouches for certificates that contain the public keys of all the entities in the system.

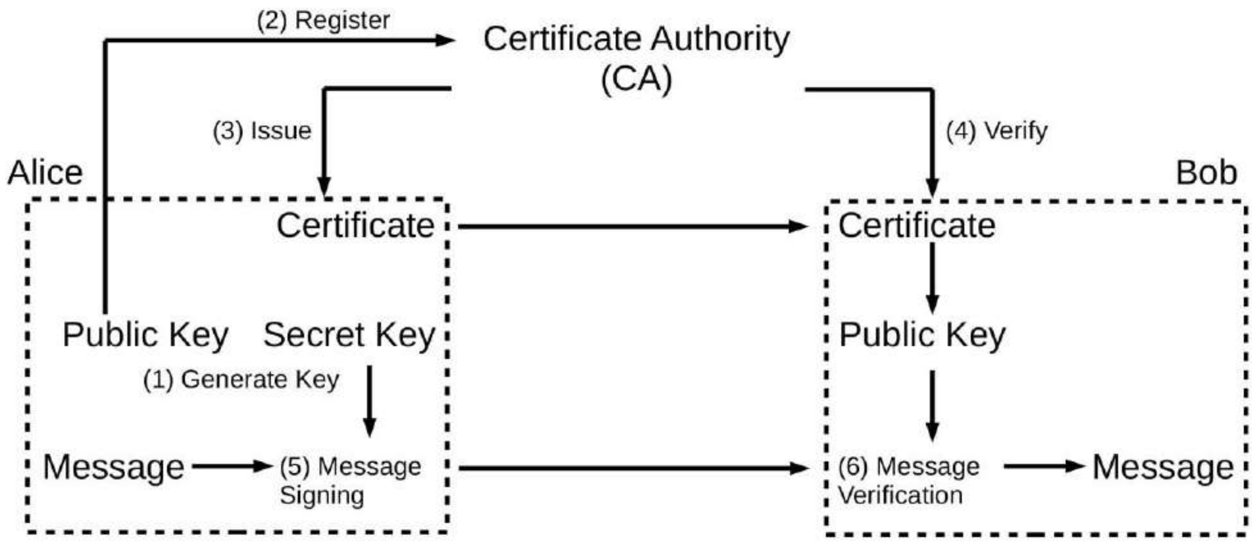

Figure 1. Signing and verifying a message using a certificate authority PKI

The impact of a compromise of the C-ITS PKI will allow attackers the ability to inject, modify and replay messages. Safety critical and traffic management messages can be falsified to cause vehicle collisions. Attacker vehicles may be able to create false identities and masquerade as emergency vehicles, thereby getting preferential treatment in traffic or send false information to vehicles to cause traffic jams and to free other roads from traffic.

The contribution of this paper is the definition of C-ITS PKI security requirements. A critique of the European Union (EU) (Bissmeyer et al., 2011) and United States (US) (Whyte et al., 2013) proposed C-ITS PKI standards is conducted and shows that neither standard fully meets the requirements set out in this paper.

This paper is constructed as follows. The next section defines the C-ITS PKI security requirements and an attack model required for C-ITS PKI systems. The third section describes the certificate provisioning and revocation processes in the EU and US standards. Following on, the fourth section analyses these two standards according to the security requirements and the final section provides a discussion and final thoughts regarding an Australian C-ITS PKI standard.

Security Requirements and Attack Model

A C-ITS PKI security requirement describes the properties that such systems should achieve. Security requirements are always described in conjunction with an attack model. The attack model defines what threats the security system should be able to protect against and the abilities of the adversary or attackers that the system is expected to defend against.

Security Requirements

Security requirements for C-ITS PKI are related to certification and validation, privacy, scalability and efficiency and revocation.

Certification and Validation

Certification and validation are the key properties of a PKI, and provide supporting security assumptions to the cryptographic algorithms and protocols used in the C-ITS. A certificate contains the public key that belongs to an entity in the system that is signed by the certificate authority. In the C-ITS all vehicles and roadside infrastructure that communicate to each other will all require certificates. The certificate is used to ensure that the public key that is received with a message belongs to the correct entity. Without certification, an attacker may be able to substitute their own public key for another entity and send messages claiming to be from that entity. If a PKI possesses the certification and verification property, the system should be able to successfully distribute and verify public key certificates belong to the correct entities.

Privacy

One of the key requirements of a C-ITS PKI is that the privacy of the car is maintained. There are two aspects of privacy. First is operational privacy. Operational privacy describes situations where cars need to be anonymous from other cars and roadside infrastructure. It is expected that cars should be anonymous while they are sending and receiving messages in normal C-ITS operations. Second is the desire for car to be anonymous from the certificate authority and the other components of the C-ITS system that make up the certificate distribution system. This second level of anonymity is much harder to achieve and requires complex systems and protocols to maintain.

Revocation

One of the key functions of a PKI system is the ability to maintain trust and security by notifying nodes of invalid or corrupted certificates. A mechanism must exist that allows the entities to recognise that the central authority no longer accepts a particular public key. This is a necessary function, as it cannot be assumed that secret keys and their associated public keys can be kept secure indefinitely. The revocation system is one that becomes problematic as the system grows. It is challenging to ensure that all system participants have up to date certificates and keys.

Scalability and Efficiency

The C-ITS PKI described in this paper are large scale infrastructures that are intended to span continents in terms of geographic scope. The means that the number of vehicles using the system is expected to run into the hundreds of millions. This is a challenge as the only other PKI system that is similar in magnitude is the one provided on the Internet. As a result of the massive scale of the PKI, all computations, communications and storage usage should be carefully considered. Part of this requirement is that these performance metrics do not place a burden on the system. The vehicle communication system must be functional despite the PKI system used to secure it. One of the other key factors in the scalability requirement is the speed which authenticated messages can be computed, transmitted and verified. Messages warning of collisions and other safety related events must be delivered with enough time to spare for a human driver to act on the contents of the message.

Attack Model

Our attack model is based on standard information security attack models for wireless sensor networks (Alzaid et al., 2008).

Attacker Abilities

Given a wireless V2V communications medium, it is assumed that the transmission medium cannot be physically protected from the attacker. The attacker is capable of viewing all messages transmitted across the network between the car and the PKI authority servers. In addition, the attacker should be able to inject, modify and replay any messages that it has encountered before. The attacker has full control of the network between the PKI authority servers and the car.

Attacker Behaviour

The aim of the attacker is to undermine or prevent the security properties previously described from being provided. In terms of privacy, an attacker will seek to determine the true identity of the car and link the car to multiple operations or locations in the PKI system. In terms of certification, the attacker would like the car to accept an invalid or previously revoked public key certificate.

Target Vulnerabilities

It is also possible that the attacker is able to gain control of the in-car Controller Area Network (CAN) bus. Thus the attacker may be able to control aspects of this network. However, it is assumed that the long-term private keys and session keys used in the PKI are stored on board the car in a secure storage facility such as a Trusted Platform Module (TPM).

C-ITS PKI Standards

This section will describe generic C-ITS PKI schemes that are the core of the EU (Bissmeyer et al., 2011) and US standards (Whyte et al., 2013).

EU Standard

The Car-2-Car Communication Consortium (C2C-CC) is a EU industry forum on car-to-car and infrastructure communication technologies. This forum presented a PKI organisation and structure that issues certificates to car to other device (C2X) enabled units. The PKI was specifically designed to have minimum overhead and maximum scalability while preserving privacy.

The C2X PKI consists of three main stationary authority entities: the Root Certificate Authority (RCA), the Long Term Certificate Authority (LTCA) and multiple Pseudonym Certificate Authorities (PCA). These authorities interact with typical ITS endpoints that include cars, ITS central traffic management stations, or ITS roadside stations. For the purpose of our paper all of the ITS endpoints can be considered to be the same and are referred to as cars.

Certificate Provisioning

The RCA is the central trust anchor that is responsible for establishing the trust of multiple LTCAs and PCAs. The LTCA is responsible for issuing a Long Term Certificate (LTC) to each car. The certificate will identify and authenticate each node in the system but it is not used for wireless communication. The PCA is responsible for issuing pseudonym certificates that are used for wireless communications. The car sends a certificate request to the local PCA. The PCA forwards the request to the LTCA if it is in the correct jurisdiction for the LTCA. Otherwise the request is forwarded to another PCA. The LTCA verifies whether the car is allowed to exist on the network, and instructs the PCA to issue a signed pseudonym certificate to the ITS. The EU Certificate Provisioning scheme presented uses the PCA to obscure and therefore provide privacy between the ITS and the LTCA.

Certificate Revocation

The EU standard for certificate revocation does not rely on Certificate Revocation Lists (CRLs). The system relies on the Registration Authority (RA) or other entity to report the revocation of a car's certificate to the LTCA. The LTCA records the status of the car and waits for a pseudonym request from the PCA. The LTCA checks the status of the car each time a pseudonym certificate is requested and then rejects the certificate if the car is to be revoked.

US Standard

The US Department of Transportation has also recommended a V2V communications PKI called the Security Credential Management System (SCMS). In comparison with the EU Standard, the US standard is far more complex. The SCMS requires up to five authority servers and ten message communications to complete the certificate provisioning protocol. The authority servers include a Linkage Obscurer Proxy (LOP), Registration Authority (RA), two Linkage Authorities (LA_1, LA_2) and a Pseudonym Certificate Authority (PCA).

Certificate Provisioning

To get a certificate, the car must first send the certificate request to the LOP which will obscure any identifying details of the request such as the location details and forward it on to the RA. If the request is valid, the RA will send an acknowledgment back to the car. However, the RA does not immediately send back the requested certificates to the car even though an acknowledgment message is returned to the car. Instead the RA waits for a number of requests before proceeding to hide the identity of requesters from the PCA. To create a pseudonym certificate, the RA collects encrypted keying material pre-linkage values from LA_1 and LA_2 and includes them in the request to the PCA for a pseudonym certificate. Two linkage authorities are required so that no single linkage authority may hold the linkage values for a particular device, and thus be able to track it. The PCA sends the pseudonym certificate containing the public key and hash of the certificate to the RA. As part of the pseudonym certificate the PCA obscures the pseudonym certificates to ensure that the RA is not able to recognise any pseudonym public keys that it is distributing. The RA returns the collected super-batch of pseudonym certificates to the car via the LOP obscuring identification details.

Certificate Revocation

Any car or roadside device may report misbehaviour to the Misbehaviour Authority (MA) who is responsible for overseeing the certificate revocation process. The certificate revocation process is similar to the certificate provisioning process in reverse. The reporting device has to simply send the pseudonym certificate belonging to the offending device to the MA through a LOP. The MA requests initial keying materials from the PCA. The MA then sends the certificate request hash to the RA so that it can be added to the revocation blacklist. The MA also sends the keying material to the two Linkage Authorities so that it can request the linkage seed for the current time period. The linkage seed allows the system to detect and reject all future pseudonym certificates related to a particular certificate-provisioning request. Due to the nature of hash chains the RA will not be able to find and reject pseudonym certificates used earlier than time period. The MA adds the keying materials as well as the time period in the Certificate Revocation List (CRL). The CRL is then distributed to all devices that may receive pseudonym certificates.

Analysis

This section provides an informal analysis of the C-ITS PKI proposals with respect to the security requirements defined earlier.

Certification and Validation Issues

This section considers practical implementation issues with the EU and US cryptographic protocols and primitives that are used in the certification and validation of vehicle public keys.

Weaknesses in Cryptographic Primitives

Cryptographic algorithms and protocols are the building blocks of security and privacy on the Internet and are a core part of all C-ITS PKI proposals. Cryptographic algorithms are continually being improved as researchers break the security of old schemes or propose new more efficient schemes. Modern cryptographic protocols such as Secure Shell (SSH) and Secure Socket Layers (SSL) include a built in negotiation process to select common cryptographic algorithm. Protocols in the C-ITS PKI systems should be flexible enough to allow the negotiation of cryptographic protocols. Although this may leave things open for downgrading attacks.

Efficiency of Cryptographic Protocols

The EU standard does not use any special cryptographic protocols to reduce communication traffic. In comparison, the US standard proposal incorporates cryptographic mechanisms for ensuring the scalable generation of public key certificates. A relatively small amount of data is required when distributing the certificates in the US standard because of the butterfly key mechanism. However, the same amount of data is still required to be returned to the car when the PCA has generated the certificates. New cryptographic protocols can be designed to allow reduced communication protocols. Though this may require more trust and computation on board the car.

Privacy Issues

Privacy for certificate provisioning in the EU standard is provided by encrypting the signer ID of the LTC thereby obscuring the identity of the car from the PCA. To ensure that privacy is maintained against an adversary that monitors all traffic to and from the car, the car is required to store a number of pseudonym certificates (around 2000) at any one time. The car randomly selects certificates to use during communications. If the stored number of certificates is insufficient it will reuse them or request more certificates. There is a performance requirement in that the symmetric decryption key needs to be requested before the pseudonym certificate can be used.

The certificate provisioning process in the US standard is complicated because of the multiple entities involved and the fact that each of these entities must hide information from the other entities to ensure the privacy of the car and its pseudonyms. The blinding process involves cryptographic mechanisms, but also there is a need to store messages for some time so that traffic communication cannot be analysed. This will impact on the efficiency of the provisioning process. It is not recommended that the RA stores these values as it can then start to collect information that may allow it to link pseudonym certificates together.

Revocation issues

The major issue with the EU standard key revocation process is that an adversary-controlled car can continue to send invalid messages until it runs out of pseudonym certificates. This may be some time as cars are expected to store up to 2000 certificates.

There are issues with the US standard key revocation process in that it is assumed that all misbehaviour reports are valid. However, if this is request is submitted through a LOP, bogus misbehaviour reports may be submitted without being able to determine who submitted them. Thus a malicious attacker may have a car incorrectly revoked from the system.

The more entries in the CRL means that more linkage seeds must be verified by messages receivers before they can trust and act on the message. A malicious attacker could slow the system by reporting many invalid pseudonym certificates thereby greatly increasing CRL entries.

The US standard does have a weakness in the revocation process. If a car strays out of CRL broadcast range, they may not be updated with the latest CRL. An attacker blocking the signal to the car and preventing it from receiving the CRL update will achieve the same result. Thus the car will accept revoked certificate because it does not know that it is on the CRL. A car can also be tricked into accepting an expired out of date certificate (certificates usually have an expiry date). If the clock in a car is changed or naturally too slow, the car may accept an expired certificate. Most cars should be able to synchronise their clocks from a GPS signal, but this signal can be spoofed or blocked. Attackers can also target the timing system if they know this is a specific vulnerability that will work.

Scalability and Efficiency Issues

Certificate Provisioning Issues

Both the EU and US standards of securing V2V communications relies on a centralised certificate authority model of trust similar to the Internet. The Internet PKI in 2010 had around 650 organisations distributed worldwide providing certificate provisioning (Eckersley & Burns, 2010). It is roughly estimated in August 2012 that there is anywhere between 2.5 to 4 million certificates in use, with the figure increasing every year (Duncan, 2015). The number of certificate revocations may provide an indication on the number of certificates being issued to replace the revoked certificates. Between January 2012 to June 2014, the SANS institute estimated that approximately 1.5 million certificates were revoked (Vandeven, 2014). Although this figure includes certificates, which have ceased operation, where no replacement certificate is generated, this data provides insight on the order of magnitude of certificate provisioning on the Internet.

In comparison to the Internet PKI model, the C-ITS PKI will have to provide a significantly larger amount of certificate provisioning. The US model alone will have to support 350 million cars at full implementation, with that number continually increasing. To provide privacy, each car will need 40 pseudonym certificates per week, equating to 14 billion certificates provisioned each week.

Assuming a best-case scenario of a uniform distribution of certificate provisioning over the course of the week, the C-ITS PKI would have to provision 23,000 pseudonym certificates per second. Given modern computing power, such a load is feasible. However, due to geography and driving patterns, some infrastructure may experience higher than normal loads, as certificate provisioning would occur in a non-uniform distribution. There is an order of magnitude difference in number of certificates to issue and revoke for the C-ITS PKI which highlights a scalability issue. Although the number of entities in Australia is considerably less than the US and EU, the number of certificates provisioned annually still significantly exceeds the number of certificates the Internet provisions. Even under this reduced load, certificate provisioning and revocation for an Australian V2V system highlights a scalability issue.

Table 1. Certificate Comparison between Internet and C-ITS PKI

	Internet	**V2V (US)**	**V2V (AU)**
Number of Entities	1 Billion +	350 Million +	18 Million +
Certificates Provisioned (Annually)	1 to 2 Million*	278 Billion	37.4 Billion
Certificates Provisioned (Weekly)	19,000 to 38,000^	14 Billion	720 Million
Certificates Provisioned (Per Second)	-	23,000^	1190^
CRL Number of Entries	136,000#	-	-
CRL File Size	5.0 Mb#	Estimated 300 bytes to 2Mb+	Estimated 300 bytes to 2Mb+

* Based on estimations of revocation and expiry dates of certificates. ^ Assuming uniform distribution. # As of July 2015

Certificate Revocation Issues

With certificate provisioning orders of magnitude greater in the V2V network when compared to the Internet, even for an Australian V2V system, certificate revocation will also pose a scalability challenge. Although the certificate revocation details in the US standard are still yet to be finalised, there are several important considerations.

The first is the size of the CRL file. With a large number of entities in the network, and more certificates provisioned in a week in the V2V network than over the Internet in a year, the CRL file size may become very large. Currently, the SANS institute uses the Global Sign CRL list (GlobalSign, 2015), which as of July 2015 contained approximately 136,000 serial numbers of revoked certificates totalling to a CRL file size of 5.0 Mb. These include certificates revoked over a 4-year period since June 2011. Assuming the conservative estimate of a V2V CRL file size to be 5 MB, under the DSRC WAVE protocol (Li, 2010), each car would require 1.5 to 13 seconds to receive the CRL. PKI implementations using CRLs for certificate revocation are communications heavy (Naor & Nissim, 2000). A more efficient method called Online Certificate Status Protocol (OCSP) reduces the communications overhead, however requires the car to poll a server to verify the validity of a certificate. This may be infeasible in a large geographic expanse that a V2V network will cover.

The second consideration is the subject to a Denial of Service (DoS). CRLs typically have a short validity period to ensure freshness of data. When they expire, the entity will poll the CRL distributor for a new or fresh CRL to prevent a replay attack using an old CRL. However, if a new CRL cannot be obtained before the previous one expires, the entity will be subject to a DoS. The CRL in this instance provides the only method of determining the validity or authenticity of an unexpired certificate. As a result, operations involving that certificate, such as verifying the authenticity of a message signed by that certificate cannot take place.

A possible solution to both these considerations is to use Delta CRLs, where only the changes to a CRL are distributed. Disseminating only the differences would reduce the communications overhead, whilst regular updates when in communications range would provide freshness of data. As each car maintains their own CRL, replay attacks on older CRLs being distributed can be avoided provided that CRL entries in each car could not be deleted.

Discussion and Conclusion

There are still a number of challenges for deploying a secure and effective C-ITS PKI. Australia has a large geographic environment, with large distances between cities. This differs from the EU and US standard environments with more regular interspersed urban centres. The proposed EU and US schemes therefore assume regular communications with central authorities for certificate provisioning and revocation. The challenges in deploying a C-ITS PKI in Australia would have to address the potential disruptions in network connectivity between vehicles and a central authority. As with the US and EU, the use of a more distributed and decentralised PKI architecture may be more applicable to deploying a C-ITS PKI, particularly in Australia with our large geographic environment and multiple state government agencies. However a decentralised system will make large-scale accurate certificate revocation more challenging.

The EU and US standards use the concept of pseudonyms to provide privacy. Currently, license plates on vehicles behave like pseudonymous identifiers that can be at any time revoked by transport registration authorities. Australia should consider whether the need for privacy from the authority entities in the Australian C-ITS PKI is necessary. This privacy requirement adds most of the complexity to the C-ITS PKI standards. It may be that there is a need for identities to be revealed under certain conditions such as when a legal warrant is provided.

The Australian C-ITS PKI standard is still unknown but it should take lessons from the EU and US. Both standards deal with complex interactions with multiple authorities. Australia should limit the number of authorities with a uniform standard across the country and extended trusted communications between regional transport registration authorities. A simpler C-ITS PKI system design with less reliance on centralised authorities will ensure a successful implementation and cost effective operation.

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Left on the Side of the Road? A Review of Deterrence-Based Theoretical Developments in Road Safety

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Abstract

Deterrence-based initiatives form a cornerstone of many road safety countermeasures. This approach is informed by Classical Deterrence Theory, which proposes that individuals will be deterred from committing offences if they fear the perceived consequences of the act, especially the perceived certainty, severity and swiftness of sanctions. While deterrence-based countermeasures have proven effective in reducing a range of illegal driving behaviours known to cause crashes such as speeding and drink driving, the exact level of exposure, and how the process works, remains unknown. As a result the current study involved a systematic review of the literature to identify theoretical advancements within deterrence theory that has informed evidence-based practice. Studies that reported on perceptual deterrence between 1950 and June 2015 were searched in electronic databases including PsychINFO and ScienceDirect, both within road safety and non-road safety fields. This review indicated that scientific efforts to understand deterrence processes for road safety were most intense during the 1970s and 1980s. This era produced competing theories that postulated both legal and non-legal factors can influence offending behaviours. Since this time, little theoretical progression has been made in the road safety arena, apart from Stafford and Warr's (1993) reconceptualisation of deterrence that illuminated the important issue of punishment avoidance. In contrast, the broader field of criminology has continued to advance theoretical knowledge by investigating a range of individual difference-based factors proposed to influence deterrent processes, including: moral inhibition, social bonding, self-control, tendencies to discount the future, etc. However, this scientific knowledge has not been directed towards identifying how to best utilise deterrence mechanisms to improve road safety. This paper will highlight the implications of this lack of progression and provide direction for future research.

Introduction

The significance of improving road safety continues to be reflected in the range of countermeasures and interventions that are currently being implemented to reduce traffic violations (e.g., law enforcement initiatives). The majority of these countermeasures utilise (or are founded upon) deterrence theory, which is central to criminal justice policy (Piquero et al., 2011). In regards to deterrence, the Classical Deterrence theory remains the mostly widely cited model, and it proposes that individuals will avoid offending behaviour(s) if they fear the perceived consequences of the act (Homel, 1988; Von Hirsch et al., 1999). The model was originally developed by two 18th century utilitarian philosophers named Bentham and Beccaria and proposes that offending behaviours are inversely related to the certainty, severity and swiftness of punishment (Taxman & Piquero, 1998). That is, the threat of legal sanctions are most effective when individuals perceive a high likelihood of apprehension when committing an illegal act, and believe that the impending punishment will be both severe and swift (Homel, 1988). This is known as *general deterrence*. In contrast, *specific deterrence* is the process whereby an individual who has been apprehended and punished for a criminal act refrains from further offending behaviour for fear of incurring additional punishment (Homel, 1988). The primary focus of this review is on general deterrence, although specific deterrence is still of relevance (and difficult to ignore) when examining the impact of different road safety countermeasures. Given the increasing utilisation of deterrence-based approaches in road safety (e.g., the expansion of random drug testing initiatives and speed cameras) it is timely to consider evidence regarding the effectiveness of the approach. It is also timely to consider whether theoretical progression of deterrence-based theory has kept pace with its corresponding application.

Method

The systematic review incorporated core principles of the "Preferred Reporting Items for Systematic reviews and Meta-Analyses" (PRISMA) statement checklist, including defining: (a) eligibility criteria e.g., studies between 1960 and 2015, (b) information sources e.g., electronic databases, reference lists, (c) study selection approach e.g., peer reviewed publications, and (e) study characteristics. However, given a primary aim of the study was to focus on the existence of theoretical progression (rather than effect sizes) the review focused on identifying (rather than quantifying the impact of) deterrence-based road safety research. Studies that reported on perceptual deterrence between 1960 and June 2015 were searched in electronic databases including PsychINFO and ScienceDirect. Key words were used such as: Classic deterrence doctrine, perceptual deterrence, certainty, severity, swiftness of sanctions. This was supplemented with scanning of reference lists of relevant manuscripts to identify other studies of direct relevance, including in the "grey literature." Studies that focused on drink driving, speeding and other road safety violations as well as broader criminological publications were included.

Results

Certainty, Severity and Swiftness

In regards to the three factors of Classic Deterrence, a considerable body of broader criminological research has demonstrated a significant (although relatively weak), negative relationship between certainty of arrest and a variety of crime rates (Grasmick et al., 1983; Grosvenor, Toomey & Wagenaar, 1999; Silberman, 1976; Sherman & Berk, 1984; Teevan, 1976; Von Hirsch et al., 1999). In regards to road safety, the findings have not been so clear. Australian speeding-based studies have indicated that greater certainty of punishment predicted more frequent speeding (Fleiter et al., 2009; Fleiter & Watson, 2006). However at an aggregate level, increasing the perceived likelihood of detection has been demonstrated to be effective, particularly in the area of drink driving with the introduction of random breath testing (RBT) (Harrison, et al., 2003; Henstridge, Homel & Mackay, 1997; Watson et al., 2005). It may be suggested that the effectiveness of RBT is (in part) based on increasing the perceived likelihood of detection (Davey & Freeman, 2011), although evidence remains that higher levels of perceived apprehension related to RBT does not always produce a strong deterrent effect (Watson & Freeman, 2007). This disparity may suggest that individual differences exist in motorists' responses to the threat of apprehension, which has been reported in the broader criminological literature (Piquero et al., 2011) and is considered below.

Published results into the perceived severity of legal sanctions have also been conflicting. Some early criminological research reported a weak, negative relationship between perceived severity of sanctions and a range of illegal behaviours (Grasmick & Bryjak, 1980; Klepper & Nagin, 1989; Paternoster & Iovanni, 1986; Teevan, 1976; Tittle, 1980). An opposing body of research (including within the road safety field) demonstrates that the perceived severity of penalties does not have the desired deterrent impact (Decker et al., 1993; Homel, 1988, Paternoster & Iovanni, 1986; Piquero & Pogarsky, 2002; Ross, 1982; Teevan, 1976). In fact, for specific deterrence, some studies have reported a counter-intuitive relationship, with crime rates actually increasing with increases in the severity of the penalty (Mann et al., 1991; Silberman, 1976; Tittle, 1980) or offenders remaining impervious (e.g., recidivist drink drivers) (Freeman et al., 2006; Lenton, Fetherston & Cercarelli, 2010). For speeding behaviours, a comparative study of Australian and Chinese motorists found that penalties were not viewed as particularly harsh for the Chinese (Fleiter et al., 2009). Some studies on drink drivers report that punished offenders were more likely to re-offend (Piquero & Paternoster, 1998) or sanctions do not reduce drink driving recidivism, after controlling for alcohol-related problems (Yu, 2000). Piquero and Pogatsky (2003) considered this to be a “resetting effect”, whereby offenders believe they are less likely to be apprehended again soon after coming in contact with the police. In New South Wales, no significant deterrent effect was found for higher fines imposed by magistrates (Weatherburn & Moffatt, 2011). However, it is also noted an opposing body of research has demonstrated that sanctions have the capacity to reduce the likelihood of re-offending for a range of offences including speeding (Elvik & Christensen, 2007; Paola, Scoppa & Falcone, 2010), unlicensed driving (Siskind, 1996; Voas, Tippetts & Lange, 1997), and drink driving (Homel, 1988). A clear example of this was the 2003 introduction of a penalty point system for driving offences in Italy that demonstrated a significant reduction in aberrant driving behaviours (Paola et al., 2010). Researchers have further suggested that a critical relationship exists between perceived certainty and severity, as punishment severity only creates a deterrent effect when the perceived likelihood of apprehension is high (Grasmick & Byrjak, 1980; Howe & Loftus, 1996).

The third aspect of Classic Deterrence (e.g., swiftness of sanctions) has received less attention (Babor et al., 2003; Nagin & Pogarsky, 2001). This may be considered surprising given that models of learning and experimental psychology demonstrate that the time between stimulus and response is vital for learning new behaviours (Nagin & Pogarsky, 2001). Nevertheless, it has been suggested that this is because penalties are rarely applied swiftly in the criminal justice system (Babor et al., 2003) and scant research has shown that motorists do not believe penalties are delivered quickly (Fleiter et al., 2010). Taken together, empirical support for the principles of Classic Deterrence has been mixed (Davey & Freeman, 2011). This outcome has been suggested to be dependent upon the fact that the: (a) model is not a comprehensive theoretical explanation of human behaviour and (b) the differences between objective and perceptual punishment are rarely considered (Fleiter, Watson, & Lennon, 2013).

Extending Deterrence Theory: Non-Legal Sanctions

A number of models have stemmed from, or expanded the scope of, Classical Deterrence Theory. The earliest attempt at theoretical expansion commenced with an examination into the deterrent effect that non-legal sanctions have on decisions to commit an offence (e.g., Social Control Theory). This resulted from recognition that penalties are not applied within a social vacuum (Berger & Snortum, 1986; Sherman, 1993). Scientific efforts to understand deterrence processes were most intense during the 1970s (Andenaes, 1974; Gibbs, 1975; Zimring & Hawkins, 1973) and 1980s (Cornish & Clarke, 1986; Homel, 1988; Ross, 1984; Vingilis & Mann, 1985; Williams & Hawkins, 1986). This era produced competing theories that included both legal and non-legal factors, as well as preliminary work into the perceived personal benefits of crime (Katz, 1988). In fact, the literature associated with this period bristles with reviews, theoretical arguments, reconceptualisations and rebuttals (Homel, 1988). A range of social, developmental and environmental factors were proposed in an attempt to understand a range of criminal activities (Davey & Freeman, 2011), which eventually extended beyond purely deterrence-frameworks to include a range of sociological and psychological principles, such as Akers (1977) Social Learning Theory.

Within the road safety arena, this theoretical work culminated in the development of three prominent drink driving models proposed by: Ross (1982), Laurence, Snortum and Zimring (1988) and Homel (1988). The latter Australian-based researcher included three non-legal constructs in the model: (a) social loss (e.g., peer disapproval), (b) physical loss (e.g., injury) and (c) internal loss (e.g., feeling ashamed). However, since their inception, these models have not been extensively utilised to examine traffic offences. Nevertheless, in the wider criminological field, social disapproval or fear of social stigma have shown to produce a significant deterrent effect on a number of illegal acts such as shoplifting, violent offences, etc (Von Hirsch et al., 1999; Paternoster & Iovanni, 1986; Tittle, 1980). In fact, some researchers have reported that the threat of informal sanctions produces a greater deterrent effect than legal sanctions (Tittle, 1980; Laurence et al., 1988). While this may not be the case for recidivist drink drivers (Freeman et al., 2006), the threat of crashing the vehicle as well as hurting another motorist can influence drink driving behaviours among general motorists (Baum, 1999; Freeman & Watson, 2009).

Extending Deterrence Theory: Punishment Avoidance

Another prominent direction of deterrence-based theoretical development (that also continued to consider the effect of social influence) focused on the effect of punishment avoidance. Stafford and Warr (1993) proposed a reconceptualised model of deterrence that incorporates four categories of experiences that have been suggested to affect deterrent process, which are: a) direct experience of punishment; b) direct experience of punishment avoidance; c) indirect (vicarious) experience of punishment; and d) indirect (vicarious) experience with punishment avoidance. As such, concepts of punishment and punishment avoidance were proposed to be central to the expansion of deterrence theory, which may prove particularly relevant for road safety research given that it has been estimated the chances of being apprehended for some offences is low (Voas, 1982). Interestingly, this is one of the few theories where the level of theoretical application is perhaps greater within the road safety arena compared to criminology. In regards to criminological research, Paternoster and Piquero (1995) reported that punishment avoidance is negatively associated with perceptions of arrest certainty, and positively associated with illegal drug use in high schools. In regards to road safety, Piquero and Paternoster (1998) re-examined Snortum and Berger’s (1989) data of 1,686 general motorists in the United States and reported higher levels of personal experience with punishment avoidance was a predictor of intentions to drink and drive again in the future. Piquero and Pogarsky (2002) reported a similar result in a sample of 250 college students. Vicarious and personal punishment avoidance experiences have also been demonstrated to be most closely associated with drug driving behaviours (Armstrong, Wills & Watson, 2005; Watling, Freeman, Palk & Davey, 2011), although such effects may differ with gender (Watling et al., 2011). Similar findings have been found for speeding (Fleiter & Watson, 2006), unlicensed driving (Watson, 2004) and recidivist drink driving behaviours (Freeman & Watson, 2006). Researchers have also combined this model with Social Learning Theory (Akers, 1977) to further explore the aetiology of offending behaviours (Fleiter et al., 2013), although such a review is beyond the scope of the current paper e.g., includes operant conditioning and vicarious learning.

Expanding Deterrence Theory: Criminology Research

The review of the deterrence literature indicated that criminological research has continued to make theoretical advances in determining the conditions under which sanctions affect compliance, particularly in regards to individual differences. This has included what types of persons are deterred, as well as for whom sanctions either make things worse or are simply irrelevant (Piquero et al., 2011). Table 1 outlines key theoretical developments that have emerged from the criminological literature. A complete review of the literature is beyond the scope of the current paper, and other purely criminology-based reviews exist (Kennedy, 2009; Piquero et al., 2011; Pratt et al., 2006). Some brief highlights are discussed below.

While road safety researchers often include the effect of informal sanctions within deterrence models (Freeman, 2006; Homel, 1988), criminological research has further extended this concept through social bonding concepts to include *present orientation* and *self-centeredness* (Nagin & Paternoster, 1994). An extension of social bonding is an individual's moral commitment to the law (Piquero et al., 2011), which also has clear links to research on defiance theory (Sherman, 1993). Although this avenue of research focuses more heavily on responses to the application of sanctions (e.g., specific deterrence [Scheff & Retzinger, 1991; Tyler, 1990]). The concept of defiance has also received considerable attention within the broader criminological field, which has indicated that deviance towards regulatory bodies can become a way of life that is a defensible lifestyle and subculture (Braithwaite, 1989). While road safety research has regularly considered the influence of impulsivity, particularly among younger cohorts (Scott-Parker et al., 2013), it has rarely been considered in regards to deterrence nor those who have a tendency to devalue future consequences of behaviour (Nagin & Pogarsky, 2001). In fact, criminological-based research has demonstrated that lower self-control positively correlates with higher perceptions of offending benefits (Piquero & Tibbetts, 1996). Criminological researchers have actually developed a discount rate for expected utility models of deterrence (Nagin & Pogarsky 2001, 2004), which may hold considerable merit if applied to road safety analyses (e.g., benefits of speeding versus risk of being caught). An extension of impulsivity-based research has been directed towards levels of arousal (Zimring & Hawkins, 1973), which has revealed that arousal levels are not mediated by deterrence constructs (Bouffard, 2002). Additionally, levels of anger influence how rational choice factors are interpreted. This has clear implications for a range of driving tasks (not least understanding aggressive violations and hooning behaviours), although such research has yet to be undertaken.

Table 1. Individual Differences-based Research in the Criminological Deterrence Paradigm

Factor	Findings
Social Bonding	- Being well bonded to society (e.g., marriage and employment) enhances the impact of sanctions (Sherman & Berk, 1984); - Poor social bonds and ties enhance the effects of sanctions (Sherman, 1993)
Morality and Respect for the Law	- Moral commitment to the law restrains offending behaviours (Paternoster & Simpson, 1996); - Disrespect for the sanctioning body can lead to self-righteousness and further offending behaviour (Scheff & Retzinger, 1991); - Increased levels of sanctions and/or incentives are required when moral attachment is low (Etzioni, 1988).
Deviance	- Tittle (1995) identified six different categories of nonconformity that vary in levels of deviance and social acceptability; - Deviance becomes a way of life that is a defensible lifestyle and subculture (Braithwaite, 1989); - Those less bonded to society and the norm will align with social and cultural outgroups (Sanson et al., 1996).
Impulsivity and Discounting the Future	- Offending is increased among those who devalue future consequences (Wilson & Herrnestein, 1985); - Informal sanctions interact with impulsivity (Nagin & Paternoster, 1994); - Sanction severity diminishes with more presented orientated individuals (Nagin & Pogarsky, 2001).
Emotional and Pharmacological	- Individuals may perceive the threat of sanctions differently under different

Arousal	states of emotional arousal (Loewenstein et al., 1997); - Arousal levels are not mediated by deterrence constructs (Bouffard, 2002).

Unanswered Questions: Directions for Future Research

In addition to the lack of theoretical progression within the road safety arena (outlined above), a number of outstanding questions remain. The most controversial feature of deterrence-based research has been the chronological order of measuring aspects of perceptual deterrence and actual involvement in illegal behaviours (Homel, 1988), otherwise known as *causal ordering*. That is, the majority of previous research has correlated individuals' *present* perceptions of apprehension and sanction risk with self-reported *past* criminal behaviour (Minor & Harry, 1982; Paternoster, Saltzman, Waldo, & Chiricos, 1982; Saltzman et al., 1982). A limitation of this approach is that the criminal behaviour occurred before the measurement of present perceptions, and thus, these criminal behaviours may be affecting such perceptions, when in fact deterrence theory proposes that perceptions should affect subsequent criminal behaviours. As a result, researchers have argued that deterrence findings have only reported an "experiential" effect, as behaviours ultimately impact upon perceptions rather than perceptions influencing behaviours (Minor & Harry, 1982; Paternoster et al., 1982; Saltzman et al., 1982). Few attempts have been made to accommodate for such conceptual difficulties (Freeman & David, 2005), despite preliminary evidence indicating that perceptions of risk do fluctuate over time (Minor & Harry, 1982; Paternoster et al., 1982; Saltzman et al., 1982).

The lack of theoretical progression is not limited to causal ordering, but rather, a number of unanswered questions remain (briefly summarised below). These include:

a. The precise circumstances under which sanctions (or the threat of sanctions) influence or change a person's behaviour is still not well known (Davey & Freeman, 2011). In particular, further research is required to determine the conditions under which sanctions affect compliance (Piquero et al., 2011);
b. The deterrence literature generally lacks research that has examined convicted offenders (particularly repeat offenders), thus skewing scientific knowledge;
c. The bulk of published deterrence-based studies are from a small number of highly industrialised countries such as Australia, United States and Canada (Davey & Freeman, 2011). It remains unknown how deterrent forces fluctuate across environments and cultures that are rapidly embracing automobile usage;
d. Questions remain regarding the best method to isolate the degree of change from a single enforcement mechanism as well as determine an individual's knowledge of enforcement mechanisms (DeAngelo & Charness, 2012);
e. It has yet to be proven the level of rationality associated with decisions to engage in an offending behaviour (or whether they are more impulsive in nature);
f. It has long been proposed that drivers need to be constantly exposed to deterrence-based messages in order for a strong deterrent effect to be sustained, otherwise the effect is weakened (Homel, 1988). Despite the widespread use of deterrence-based enforcement approaches, it remains unknown how much exposure to roadside police enforcement techniques (and what type) is required to create a strong deterrent effect e.g., exposure to speeding cameras;
h. Questions remain how deterrence initiatives can be incorporated within a larger systems-based approach, or integrated within a broader multi-modal approach.

Discussion

This study involved a systematic review of the literature to identify theoretical advancements within deterrence theory both in regards to road safety and the wider criminological domain. The review indicated that: (a) scientific efforts to understand deterrence processes were most intense during the 1970s and 1980s, (b) the impact of deterrent approaches remains unclear and (c) criminological theorists have continued to expand deterrence knowledge, but this scientific effort is not reflected in the road safety literature. Rather, there has been little consideration of the practical application of deterrence models, not least the relationship between perceived and objective certainty of apprehension. Currently, outstanding questions remain regarding what aspects of deterrence models (e.g., legal and non-legal sanctions) create the strongest deterrent effect and should be the focus of enforcement regimes and associated media campaigns. Arguably of most importance in regards to deterring traffic violations, it remains unknown: (a) what enforcement techniques (and how much) produces the greatest deterrent effect and (b) how these enforcement techniques can be maximised (and combined with other initiatives) to improve road safety. While it may be argued that individual difference-based research is limitless within deterrence theory and the inclusion of too many factors may dilute or confuse the central aim, addressing some of these outstanding questions can only assist in attempts to reduce the personal and social burden of road crashes.

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Expanding the Victorian Alcohol Interlock program to all convicted drink-drivers

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Abstract

The Victorian Alcohol Interlock Program was established in 2003 and expanded in 2006. In 2014 the Victorian Parliament passed legislation to significantly extend the mandatory requirement for alcohol interlocks.

This initiative came into force on 1 October 2014. All drink-drivers in Victoria whose driver licences or learner permits are cancelled must now fit an alcohol interlock to any vehicle they drive once relicensed.

Alcohol Interlocks are required for all:

- Probationary and learner drink-drivers at all BAC levels;
- First time drink-drivers with a BAC over 0.07;
- First time drink-drivers with a BAC under 0.07 whose driver licences are cancelled;
- All repeat drink-drivers;
- Drivers committing offences such as refusing to provide a breath or blood sample, or culpable driving under the influence of alcohol.

The minimum cancellation period is three months and the minimum alcohol interlock condition six months.

VicRoads is now managing first-time drink-drivers whose driver licence or learner permit is cancelled and who record a BAC reading of less than 0.10. Courts continue to manage all other drink-drivers. As part of the changes, concrete criteria have been introduced for the removal of alcohol interlock conditions. Both VicRoads and the Courts will use these criteria. A new IT system supports the program.

This presentation outlines the policy decisions behind the new legislation and the challenges in implementing the expanded alcohol interlock program.

Introduction

Despite the introduction of extensive countermeasures, drink-driving remains a major contributor to road trauma. In Victoria, approximately 25% of drivers killed and 11% of drivers seriously injured are alcohol impaired. Repeat drink-drivers comprise 30% of all drink-drivers detected by Victoria Police.

Following earlier successes in reducing drink-driving brought about by reducing BAC limits, including a zero BAC requirement for novice and commercial drivers; extensive Random

Breath Testing activities; strong licence sanctions, fines and potential imprisonment; and the introduction of alcohol interlocks, the number of drink-driving crashes has stabilised.

In this context, the previous Victorian Parliament determined to take further action to tackle drink-driving. This included expanding police powers to impound the vehicles of drink-drivers; introducing a new offence of driving under the influence of both alcohol and drugs; and requiring all convicted drink-drivers to fit an alcohol interlock to any vehicle they operated.

This paper addresses the last of these measures: expanding the Victorian Alcohol Interlock Program.

The Victorian Alcohol Interlock Program

Alcohol interlocks are a proven drink-driving countermeasure, with international evidence suggesting they are highly effective in reducing drink-driving episodes while fitted (e.g. Elder, Voas, Beirness, Shults, Sleet, Nichols, and Compton R, 2011; Goodwin, Kirley, Sandt, Hall, Thomas, O'Brien, Summerlin, 2013).

The Victorian Alcohol Interlock Program was legislated in 2002 and became operational in 2003.

The Road Safety (Alcohol Interlocks) Act 2002 granted Courts the power to impose alcohol interlock conditions on drink-drivers with a first offence of 0.15 BAC or higher. Courts were required to impose an alcohol interlock condition on repeat offenders at this level. Minimum fitment periods were generally six months in duration, however a minimum three year fitment period was required for serious offences such as very high range repeat drink-driving.

Removal of an alcohol interlock condition was also managed by Courts. Offenders were required to obtain a Compliance Assessment Report from their alcohol interlock suppliers and an alcohol assessment from a drink-driving education and assessment agency. Magistrates were to take into account the offender's alcohol consumption during the alcohol interlock condition period, their 'physical and mental condition' and the wellbeing of the community in reaching a decision to remove the alcohol interlock. No set standards for these criteria were established.

The alcohol interlock program was expanded in 2006. The new legislation required alcohol interlock fitment for:

- First offenders under 26 years of age with a probationary driver licence and a BAC reading of 0.07 or more;
- First offenders aged 26 or more with a BAC reading of 0.15 or more;
- All repeat offenders with the exception of low level BAC offences;
- Refusing a blood or breath test; and
- Repeat serious alcohol-related vehicle offences under the Sentencing Act 1991, such as culpable driving

The operation of the alcohol interlock program remained largely as it was established under the 2002 legislation.

By 2014, approximately 5,400 alcohol interlock conditions were being imposed each year and the Victorian Alcohol Interlock Program had 7,500 active participants.

Commitment to expand the Victorian Alcohol Interlock Program

The Road Safety Amendment Bill 2014 included a commitment to extend the mandatory requirement for alcohol interlocks to all drink-drivers in response to the continuing contribution of drink-driving to road trauma.

VicRoads was also requested to identify the means to expand the alcohol interlock program without increasing the burden on Courts created by managing additional alcohol interlock condition impositions and removals.

These two factors, accelerated implementation and no net increase in Court burden, created policy challenges that needed to be resolved quickly in order to achieve a successful rollout of the expanded program.

Key policy challenges

1. Scope of drivers and riders included in Stage 1

Planning for the accelerated implementation of this initiative quickly revealed concerns about community readiness, complexities in the Victorian legislation and limitations in IT systems that together indicated a staged approach was warranted.

Surveys and consultations conducted in Victoria to inform the development of road safety strategies and action plans consistently indicate strong community support for measures to address drink-driving, including alcohol interlocks. However, it is a commonly held view that low level infringements by fully licensed drivers represent errors of judgement or inadvertent offending. By implication, the community believe penalties for this behaviour should not be unduly harsh.

It was felt that quickly introducing alcohol interlocks for low level BAC offences committed by full licence holders (including commercial drivers) may be poorly supported and could undermine efforts to address drink-driving. Greater community understanding that a low detected BAC reading does not correlate well with prior drinking behaviour or future offending is required, as is comfort with the widespread use of alcohol interlocks. Further work is now being conducted in Victoria to assess community support for additional drink-driving countermeasures.

Overlaying this issue, Part 5 of the Victorian Road Safety Act 1986, dealing with alcohol and drug offences, has become increasingly complex due to multiple additions and revisions since it was first drafted. This creates challenges for Victoria Police, Courts and lawyers in understanding, interpreting and applying the Act.

Addressing the complexities in the Act was outside the scope of this initiative and the compressed timeframe. To attempt to remedy this complexity would have risked delivery of the expanded alcohol interlock program. Consequently, only changes required to deliver on the government commitment were made. A project to address the complexities in the Act is in discussion at present.

The third significant challenge was that the VicRoads Driver Licensing System (DLS) is a legacy system, which is complex and expensive to change. While some revisions were inevitable given new legislation, limiting the scope of the initial changes was important for delivering on the initiative in a timely manner. The limitations of the DLS, in combination with other factors, also drove a new IT solution that became integral to the design of the expanded alcohol interlock program.

Identification of these challenges resulted in a recommendation to the previous Government to adopt a two-staged implementation approach, with most changes occurring in 2014 and the remainder to follow prior to the end of 2017. This approach was accepted.

Through the combined efforts of Victoria's road safety partners and the establishment of a dedicated project team, Stage 1 of the expanded alcohol interlock program came into force on 1 October 2014. From this date alcohol interlocks are required for all:

- Probationary and learner drink-drivers;
- First time drink-drivers with a BAC over 0.07; under 0.07 if their driver licences or learner permits are cancelled;
- All repeat drink-drivers;
- All drivers committing offences such as refusing to provide a breath or blood sample, or culpable driving under the influence of alcohol.

This means there are only two groups of drink-drivers in Victoria not subject to an alcohol interlock. The first group is full licence holders committing a first offence with a BAC reading between 0.05 and 0.07. The second group is commercial drivers with a first offence below 0.07 who are issued with a Traffic Infringement Notice but who have the matter heard by a court and successfully mount an argument for licence retention.

All drink-drivers subject to an alcohol interlock condition have their driver licences or learner permits cancelled. The shortest minimum cancellation period is three months (for learner permit and probationary licence holders) and the minimum alcohol interlock condition period six months.

Repeat offenders will continue to have 12 month (second offence) or four year (third and subsequent offence) minimum alcohol interlock condition periods.

2. Court burden

The Victorian court system, like most, experiences heavy demand. VicRoads was asked to ensure that no additional burden be placed on courts as a result of expanding the alcohol interlock program. As all offenders were being managed by courts at the time and a doubling of offender numbers was expected, this meant that an alternative management system was required.

Examination of alcohol interlock management systems across jurisdictions suggested either a fully administrative system or a hybrid administrative and court system would meet the requirement set for the Victorian Alcohol Interlock program. By partially or wholly moving offender management outside the court system, court burden could be managed.

Consideration of the options indicated that a hybrid court plus administrative system was likely to meet Victoria's needs. VicRoads would manage less complex cases: first-time drink-drivers whose driver licence or learner permit was cancelled and who recorded a BAC reading of less than 0.10. Courts would manage all other drink-drivers. This could include offenders otherwise eligible for the administrative system if they faced multiple charges.

VicRoads modelling indicated this division would result in a net reduction in court burden. It would also allow courts to focus on more serious offending where judicial management was likely to be most needed.

Drink-drivers could enter the alcohol interlock management system either through a Traffic Infringement Notice or through a court appearance. Provided that the offence met the criteria for the administrative system the offender would be managed from relicensing through to alcohol interlock condition removal by VicRoads.

As VicRoads had not previously managed alcohol interlock program participants, this decision necessitated the instigation of a major change management process within the Corporation's Registration and Licensing business. A new system was required that could manage estimated starting volumes of 5,000 new offenders per annum as well as a growing number of offenders over time who would be slower to achieve alcohol interlock condition removal or who might become in scope for VicRoads management.

3. Managing alcohol interlock performance

To address the scale and timeframe of the implementation, VicRoads created a dedicated Alcohol Interlock Project Team and multiple concurrent policy development and implementation groups.

The decision to establish an administrative process applicable to an estimated 5,000 convicted drink-drivers per annum created challenges for VicRoads in the management of offender volumes and monitoring of alcohol interlock performance.

Examination of the resource implications of manually processing this volume of drink-drivers suggested an IT solution should be investigated. While a small alcohol interlock management team would still be required even if a suitable IT solution could be procured, it was not considered sustainable to establish a large staff contingent to manually manage the volumes involved.

VicRoads therefore went to market to source an IT solution that would automate many of the tasks involved in managing drink-drivers with an alcohol interlock condition. Of the vendors short listed, it became apparent on demonstration that only one product presented to VicRoads could perform the functions required. This vendor was therefore selected to develop the new VicRoads Alcohol Interlock Management System (AIMS).

AIMS is built on web-based appointment management software, heavily modified to provide appropriate workflows for alcohol interlock condition management. AIMS is highly configurable, providing opportunities for VicRoads to make running changes and facilitating more major revisions by the vendor as required.

AIMS automatically imports offence data stored in VicRoads Driver Licensing System and creates a profile for each offender. AIMS also receives nightly data exports from alcohol interlock suppliers, establishing that an offender has an alcohol interlock installed in a vehicle, along with vehicle details, install date and other data.

At monthly servicing events, data downloaded from alcohol interlocks by service agents is transmitted to AIMS, and populates each offender's record.

Decision rules built into AIMS calculate offender performance against criteria established by VicRoads, for example vehicle use and violation counts, to determine potential readiness for alcohol interlock condition removal.

Despite the very tight timeframes involved, AIMS was ready for rollout as the first offenders under the new legislation finished their driver licence cancellation periods (end January 2015). AIMS functionality has been progressively implemented to agreed milestones, as each new system capability set has been required. This staged rollout has accommodated the accelerated implementation timetable for the alcohol interlock program while ensuring that functionality is in place when needed.

The AIMS system has a user portal that allows offenders to log in, view their status, raise queries and apply for alcohol interlock condition removal.

The monitoring and management of offender performance by a government body rather than courts challenged VicRoads and its road safety partners to develop a model that was fair and equitable to offenders but did not involve VicRoads acting as a tribunal.

The working group considering offender performance reviewed the literature and consulted subject matter experts to derive decision making principles. The available data and best practice examples together indicated a robust program would include the use of driver identification technology; compliance-based removal; support for low income offenders; and advertisement of the alcohol interlock program as a general deterrence measure.

Alcohol interlock removal criteria should be based on objective measures using alcohol interlock data and include: evidence of driver identity and vehicle usage; no attempts to start the vehicle with alcohol present for a set number of months; and no attempts to tamper with the alcohol interlock device.

These principles were used to establish a set of behavioural requirements that, if met, would qualify the offender for alcohol interlock removal.

These included that the offender must demonstrate:

- Personal usage of the vehicle in any month for which data is to count toward removal
- A minimum five months violation free interlock breath sample data immediately prior to alcohol interlock removal
- No attempts to tamper with the alcohol interlock

Offenders would be:

- Allowed to use the first month of alcohol interlock fitment as a 'learning month', where violations of the zero BAC requirement would not have negative consequences

- Permitted to have periods of non-use of the vehicle provided these did not exceed five consecutive months
- Required to restart the data collection period if consecutive non-use was 6 months or longer
- Allowed roll starts due to mechanical incidents, as long as a breath sample was provided on starting the vehicle
- Required to collect additional alcohol interlock data if they violated the zero BAC requirement or tampered with the device. The five months violation free data resets from the month following any violation
- Treated as having a mouth alcohol sample (rather than a violation) if able to record a second, 'clean' breath sample within an hour of a violation sample
- Allowed to request a review if an offender believed violations were caused by someone else

These criteria were built into the programming of the AIMS system, allowing it to automatically process and publish offender performance data.

In order for the vehicle usage requirement to be verifiable, Victoria introduced mandatory camera interlocks for offences committed after commencement of the new legislation. Photos for each month in which a vehicle is driven during the alcohol interlock condition period are visually checked by VicRoads staff to verify that the offender has driven it, and are also used to check identity if an offender claims a violation was caused by another person.

Tampering is verified by a combination of alcohol interlock event data, physical inspection by service agents and submission of a report to VicRoads.

Stakeholder agreement was reached to adopt these criteria for both VicRoads and Court managed offenders, to ensure equitable treatment and offer Courts a concrete performance standard. Courts would continue to also take other matters into account in reaching a decision about alcohol interlock condition removal.

Victoria increased support for low income offenders by extending concessions on alcohol interlock installation and maintenance to broader groups of concession card holders.

A high level TAC communications campaign across all main channels was used to advertise the changed laws and serve as a general deterrence measure. This campaign will be repeated at intervals along with other drink-driving campaigns to reinforce the messaging.

Future developments

Given that alcohol interlocks are most effective while fitted and recidivism gradually returns to pre-interlock levels (Goodwin et al, 2013), addressing the behaviour that underlies the offending will assist in maximising the long term impact of alcohol interlock programs.

1. Alcohol Interlock Data

One area already receiving attention is the more strategic use of alcohol interlock data. Rather than being used only at the end of an alcohol interlock condition to determine suitability for removal, alcohol interlock data is increasingly employed to provide ongoing behavioural feedback to users and as a trigger for further interventions with regard to alcohol use.

Violations of the zero BAC requirement during alcohol interlock fitment are commonly used as a criterion to extend the time for which the device must be used. This practice recognises that violations indicate the offender is not yet able to separate drinking from driving. The Victorian Alcohol Interlock Program intervenes in this way.

Violations, low level readings that do not trigger violations (under 0.02), mouth alcohol readings, tampering events etc. can also be used to provide behavioural messaging to offenders. These interventions can:

- support the separation of drinking from driving by warning offenders about the potential consequences of continued triggering events (such as extended device fitment periods);
- provide immediate feedback that extension or other consequences have occurred as a result of violations;
- offer tips, strategies, referral options and so on to assist in addressing alcohol consumption.

Positive reinforcement and supportive messaging can also be delivered for periods of compliance with alcohol interlock condition requirements.

The Victorian AIMS system can be configured to automatically deliver this form of intervention to program participants. VicRoads will consider how AIMS can be used to serve effective behavioural messaging that increases program compliance and potentially addresses participants' alcohol use.

2. Alcohol consumption

Addressing drink-drivers' attitudes and behaviour toward alcohol is an important measure to prevent recidivism. Education programs are a staple intervention for drink-driving, and Victoria is no different in requiring certain drink-driving cohorts to complete an alcohol education program.

Victoria also has a requirement for court-managed drink-drivers with alcohol interlock conditions to undergo an alcohol use assessment prior to removal of the interlock licence condition. The assessment occurs in the month preceding the hearing, and provides courts with information about the offender's alcohol use and therefore risk of re-offending once the alcohol interlock condition is removed.

VicRoads is interested in investigating evidence-based interventions for alcohol consumption, to establish their potential to extend the capacity of the Victorian drink-driving scheme to reduce recidivism.

Conclusion

Alcohol interlocks will remain an intervention of choice for drink-driving; their use is likely to increase across jurisdictions and cohorts of drink-drivers. Maximising the impact of alcohol interlock programs through intelligent application of interlock data and supplemental interventions that address alcohol consumption will assist in improving immediate recidivism rates and have the potential to address the longer term degradation in recidivism observed to date.

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Building New Partnerships to Improve Road Safety Risk

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Abstract

In 2012 New Zealand's KiwiRAP partners (NZ Automobile Association, NZ Transport Agency, NZ Police, Ministry of Transport, Accident Compensation Corporation), in conjunction with Auckland Transport, Tauranga City, Christchurch City and Dunedin City, took part in a national trial to more fully understand the extent of the crash problem on the urban network. As part of this trial, the successful KiwiRAP crash risk methodology was developed further for use in the analysis of the urban network and entitled Urban KiwiRAP. The Urban KiwiRAP methodology confirms that, generally, approximately 50% of death and serious injury crashes are occurring on around 10% of the urban roading network in each of the trial local authority areas.

To address death and serious injury costs and numbers by putting tools in place to identify the greatest risk of occurrence was a very new approach to injury prevention for the Accident Compensation Corporation (ACC). This organisation generally approached injury prevention from a behaviour change perspective. Changing the lens on the way injury prevention is addressed has opened the doors for new opportunities to partner with Local Authorities in the roading infrastructure space, a new direction for ACC.

This paper discusses the next steps in rolling out this new methodology to a group of Local Authority roading partners and the positive benefits that are expected from both the newly developed partnerships and the use of the Urban KiwiRAP methodology.

Background

Safer Journeys 2010-2020, New Zealand's road safety strategy (*Safer Journeys*), identified that a paradigm shift was required in the way New Zealand (NZ) viewed and approached road safety initiatives. The strategy adopted a new "Safe System" approach - a step change in thinking for road safety professionals (Figure 1).

Figure 1. The Safe System (Source: Safer Journeys)

Previous road safety practice was based on education, enforcement and engineering – the “3Es”. Investment and organisational processes to address safety were based around these three work-streams. Safety engineering interventions were generally reactive and based on social costs of crashes, resulting in “after the fact” engineering solutions every few years. Safety improvements on the network were slow and were often completed in isolation to education and enforcement initiatives. The general public saw the social cost ranking for safety projects as “waiting for someone to die” before the funding of improvements could be justified.

The Safe System approach required a different way of looking at the problem of crashes and how to address them. It identified that transport system designers and influencers share responsibility for safety along with the users of the system. It aims for *“a safe road system increasingly free of death and serious injury”.* Integrating initiatives across all pillars of the system could be expected to provide a road system with safe roads and roadsides, safe speeds, safe vehicles and safe road use.

The Accident Compensation Corporation’s (ACC) Statement of Intent 2015-2019 has injury prevention activity as one of four key areas of focus to achieve the organisational vision and values. To meet return-on-investment (ROI) goals, ACC works with partners to understand areas where injury prevention programmes can produce the greatest impacts on the severity and incidence of injury for New Zealanders. Programmes are generally developed with partners and use social marketing, community activity and learning approaches to change behaviour. Programmes also develop incentive products where appropriate behaviours are supported by levy reductions. Using passive behaviour change models, where infrastructure design moderates or influences driver behaviours or use of the road, is a new approach for ACC and not without challenges.

Introduction of New Analytical Approaches

Safer Journeys signified a shift in focus from reducing the number of crashes and fatal injuries to minimising the likelihood of high-severity crash outcomes. In order to give effect to *Safer Journeys*, new analytical approaches have been implemented to develop programmes that prioritise sites on their likelihood of future fatal and serious casualty occurrence and risk.

iRAP

The International Road Assessment Programme (iRAP) is a programme of road assessment projects being implemented in more than 70 countries around the world. The programme has a goal to reduce death and serious injury by targeting interventions to areas of the greatest risk.

KiwiRAP

In 2007-08 KiwiRAP, a development of iRAP for NZ conditions, was implemented on high speed rural State Highways. ACC was one of the partners in this project along with NZAA, MOT, NZTA, and Police.

Urban KiwiRAP

In 2012, the Transport Agency, Auckland Transport, Tauranga City, Christchurch City and Dunedin City took part in a pilot project to develop a crash risk methodology for the analysis of the local roading network based on the successful KiwiRAP. This model, Urban KiwiRAP, confirmed that, generally, approximately 50% of fatal and serious crashes were occurring on around 10% of the road network in each of the pilot local authority project areas.

The relative rarity of fatal and, to a lesser extent, serious crashes occurring at the same site is evidenced in the analysis of the crash data from the Auckland network in 2013. A study of intersection crashes showed that 79% of fatal and serious crashes occurred at sites with no fatal or serious crashes in the previous 5 years, and 64% occurred at sites with 2 or fewer injury crashes in the same period (Brodie et al, 2015). Brodie et al (2015) found that previous fatal and serious crashes were not a strong indicator of the underlying risk of future high-severity crashes for a site.

In the meantime, progress results were released for the State Highway (SH) safety improvements project, a five-year programme of safety works completed between 2007 and 2011 (see Figure 2). The results were compelling, with reductions of 15% and 13% in death and serious injury on rural and urban SH environments respectively, compared to the previous 5-years, as a result of using KiwiRAP to prioritise sites and their intervention selection. In contrast, the local road network, which was not using the model, experienced reductions of just 1% and 3% respectively.

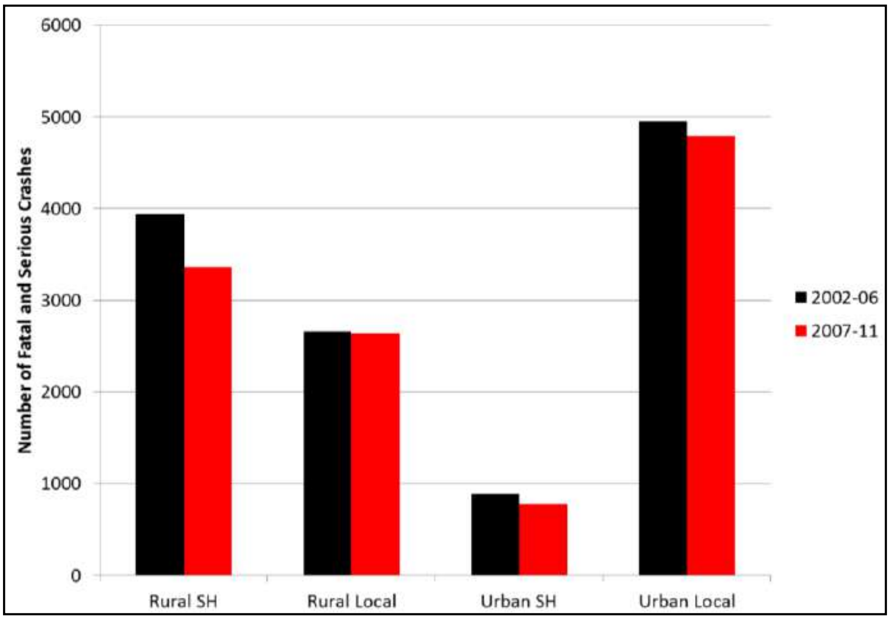

Figure 2. Comparative Safety performance of State Highways and Local Roads in Urban and Rural Environments (Source: NZTA)

These positive results encouraged another five "early adopter" Local Authorities to undertake their own risk mapping analysis using Urban KiwiRAP, alongside those in the pilot project, bringing the number of local authorities using the methodology to nine.

Urban KiwiRAP Rollout – ACC Project Rationale

The Urban KiwiRAP pilot project had demonstrated that, similar to KiwiRAP on rural state highways, the urban model would identify the 10% of the urban network where 50% of death and serious injury crashes were more likely to occur. For ACC, the opportunity to partner with local authorities and assist them by providing the information they needed to target their safety spend to this identified risk, had the potential to assist ACC with its own goal of reducing claims costs resulting from road crashes.

Four local authorities implemented Urban KiwiRAP on their networks as part of the pilot project, a total of approximately 12,500 kilometres of road. A further five local authorities have since completed risk maps (but not star rating) on approximately 10,000 kilometres of road. There are a total of 73 local authorities across NZ covering approximately 85,000 kilometres in length. Of the remaining 62 Local Authorities, a further 13, covering 10,000 kilometres of road network, were identified as generating higher costs for ACC (see Figure 3) (top group of local authority/clusters).

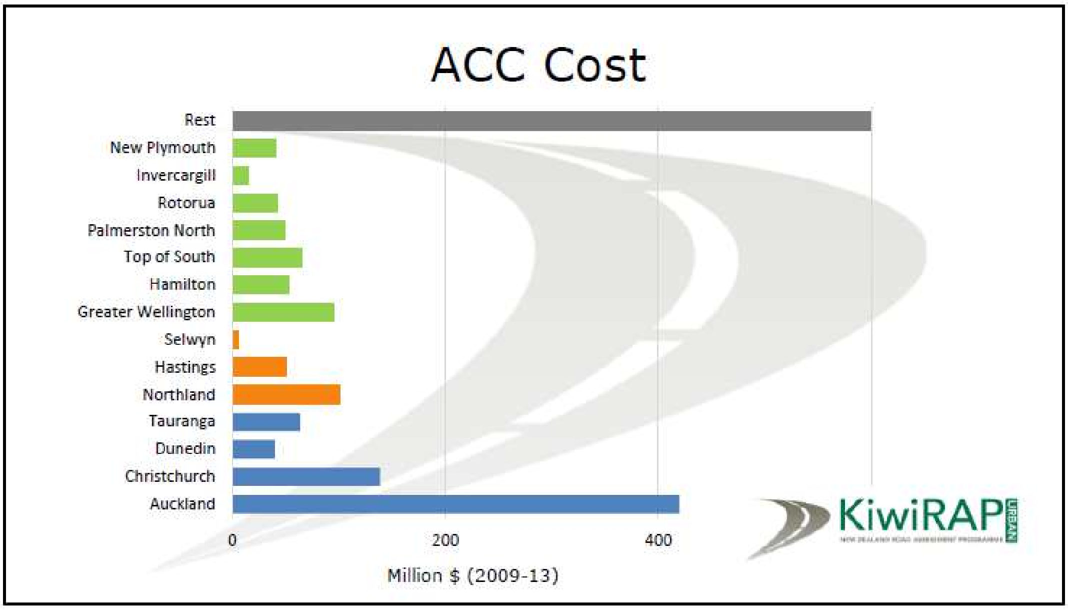

Figure 3. Cost of Claims to ACC By Local Authority/Cluster

While ACC has participated in general road safety education projects alongside NZTA, Police and local authorities for many years, ACC has not worked with local authorities in the past on infrastructure projects, despite the vast length of road in the local networks.

Despite interest in the trial project, most local authorities did not have the financial resources to take part in the Urban KiwiRAP programme. It was also assessed that not all local authorities would have enough crashes and traffic volumes on their networks to ensure the validity of this analysis and so the methodology would only be relevant to a proportion of those remaining.

Taking this into account, ACC's Urban KiwiRAP rollout project proposed extending the reach of the existing work to this next highest risk group of local authority clusters (Figure 4) (top group). This would bring the number of local authorities working proactively to treat their risk-prioritised safety issues to 22 covering approximately 32,500 kilometres of network and ensuring a statistically significant segment of data to evaluate the benefits of the programme.

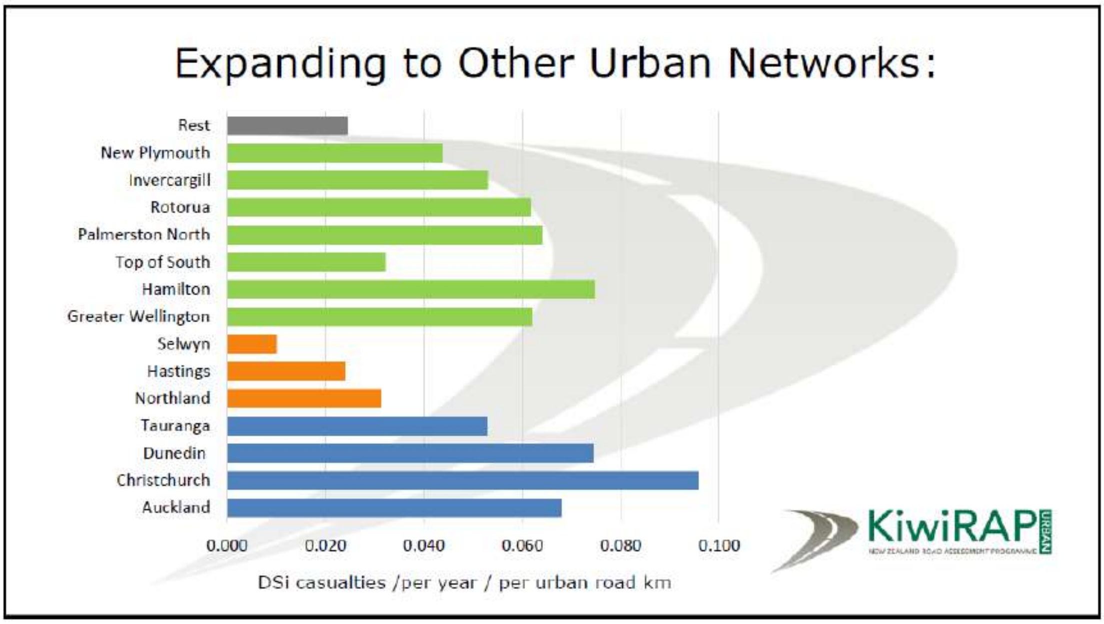

Figure 4. Next Highest Risk Group of Local Authorities by DSI casualties/year/urban road km

The local authorities were each to be provided with a set of risk maps for personal and collective risk on corridors and intersections, prioritised spread sheets of intersections and corridors for future work programme guidance, personal and collective risk for active road users and motorcycles, and approximately 100-150kms of star ratings per local authority.

ACC proposed offering this information as a partnership project – an offer of information in return for an agreement to make use of the information and allow ACC to monitoring the utility and results of using the methodology.

Road injury in the context of the Accident Compensation Scheme

While road injury contributes a small number of claims in comparison to other injury categories, the costs of these are high in the bigger picture of ACC's no-fault accident compensation scheme.

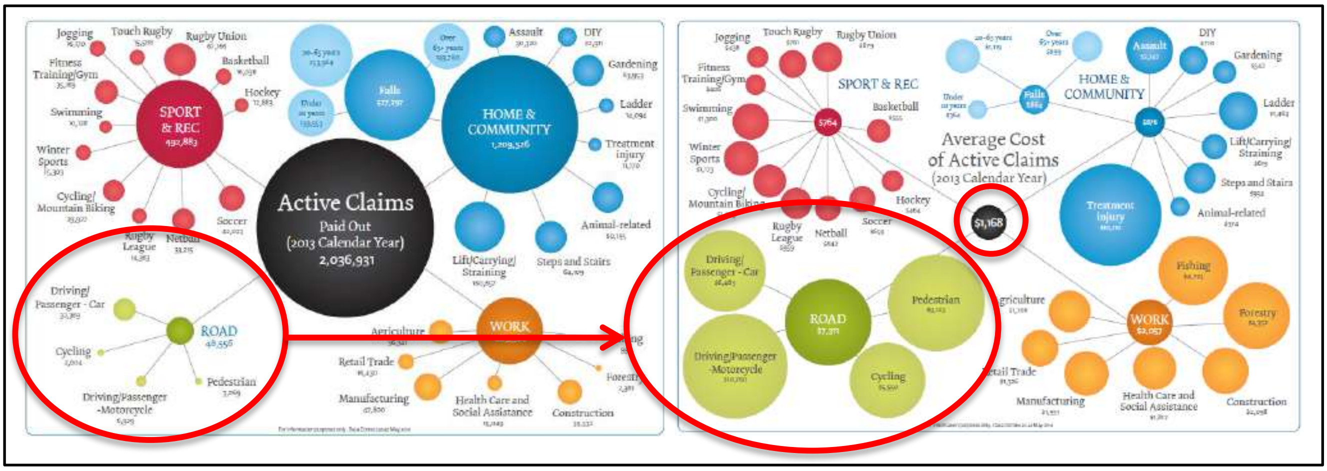

Figure 5. Significance of Road Claims to ACC – 2013 Calendar Year
Indicative Graphical Representation of Number of Claims Compared Their Average Costs

Figure 5 shows a graphical representation of the significance of road claims to ACC compared to other injury categories. On the left of the diagram, the number of active claims for the 2013 calendar year is 48,556 out of a total of 2,036,931 – road is by far the lowest contributor of active claims, at 2.4% of the total. (Active claims include those receiving ongoing payments from an injury incurred during previous years.) The cost of road claims to the scheme during 2013 was $354,976,856 of the total $2,378,885,865 - 15% of the costs to the scheme. The average cost of each active road claim is $7,311 compared to the overall scheme average of $1,168 per claim – just over 6 times the average injury cost to the scheme, see Figure 5 on the right.

The type of trauma sustained as a result of a road-related crash can result in lifelong debilitating injuries, both physical and mental, and high costs to ACC over the lifetime of the person. This serious lifelong trauma also results in ongoing costs to families and society.

Urban KiwiRAP Project Methodology

ACC (representing the KiwiRAP partnership of Ministry of Transport, NZ Police, NZ Transport Agency, NZ Automobile Association, ACC) undertook to lead and fund a rollout of Urban KiwiRAP to the identified highest risk Local Authorities. Potential partnership criteria included interest in the methodology, demonstration of leadership in the road safety area and acceptance of a partnership sealed with a Memorandum of Understanding to give clarity to the parties.

A partnering model was chosen to best represent a community development injury prevention model where people are assisted to progress at their pace to achieve their goals and, at the same time, those of partner organisations. The premise was that ACC could expect to see claim reductions become evident as partnering Local Authorities used Urban KiwiRAP to manage their road safety improvements.

The first step was to recruit Local Authority partners and an approach was made to the Transportation Managers of the higher risk local authorities identified (Figures 3 and 4) to offer a partnership with ACC. Support for the project was expected to be around 60%. At this lower response level, ACC anticipated the use of the methodology would still be likely to produce a positive return on investment over time. Instead, support was overwhelming and 100% of the identified local authorities came on board with the project (13 Local Authorities in 7 clusters).

Local Authority Transportation Managers and their engineering teams were given a short presentation about the project and how the outputs (Figure 6) could be used to their benefit. They agreed to use the Urban KiwiRAP information to assist with their forward work programme prioritisation. Risk maps and analysis would be updated as the yearly crash data became available, so the Local Authority could monitor the progress of the risk on their network.

Figure 6. Urban KiwiRAP Risk Map Outputs

The Urban KiwiRAP project provides each local authority with risk analysis for their networks in the following categories: collective and personal risk maps for corridors, intersections, and motorcycles; active road user and all-NZ motorcycle heat-maps; and a publicly viewable "averaged" layer for corridors. Additional heat maps for a variety of crash related behaviours can also be generated and are useful for assessing clusters of risk for pedestrians, cyclists, alcohol, speed, wet weather, dark.

The outputs also provide a listing of all corridor links and intersections, in order of risk, in a spreadsheet format. This provides a basic screening tool for a work programme that can be done on the desktop by experienced safety practitioners.

Use of the personal and collective risk scores provides guidance for the type of infrastructure improvement selection. Figure 7 indicates best-practice safe system treatments as recommended by NZTA's best-practice guidance in their High Risk Guides series (NZTA website). This figure shows how the measured collective-vs-personal risk output directs a treatment methodology that reflects the risk. The highest cost items are in the "safe system transformation" section and these are focussed on corridors or intersections with both med-high/high risks for both personal and collective risks. The majority of investment should be targeted at sites of higher collective risk.

Collective risk relates to the number of fatal and serious crashes occurring on a stretch of road (crash density), personal risk is the likelihood a driver will be involved in a fatal or serious crash on a stretch of road. Collective risk is the most interesting to funding agencies whereas personal risk is of more interest to the public as it shows the risk to the individual road user.

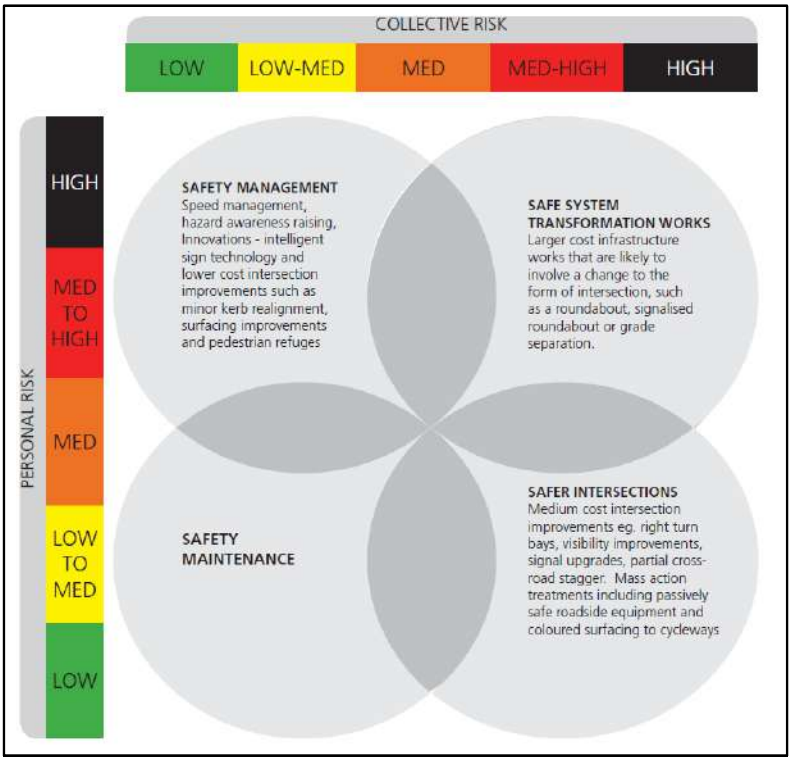

Figure 7. Infrastructure Treatments to Risk

The personal risk variable is of most interest for ACC. In these areas, where traffic volumes are low, spend on roading improvements can be difficult to justify, but from a claims perspective areas with high personal risk may be where the greater costs to ACC are occurring.

Risk outputs from this project could potentially indicate lower cost safety management and safer intersection interventions, with safety maintenance being an increased focus for network operating or maintenance contracts. Where sites have higher personal risk but low collective risk, treatment methodologies would reflect a focus on low cost treatments such as signage improvements. All local authorities approached were interested in the new methodology because they had seen good safety outcomes on the State Highways and were expecting similar reductions on their own networks.

A refined targeted-to-risk work programme has potential to provide greater opportunities for safety improvement funding. The use of the analysis may have indications for the current funding model for local authority roads if the highest-risk roads are identified but remain unfunded.

Benefits to ACC

The real value in the analysis is that, with around 50% of crashes occurring on 10% of the network, knowledge of what that looks like for a local authority and its community and politicians should translate to an increased focus on refined targeted-to-risk safety improvements. If more people are presented with clear information about risk on their roading networks, a quite different conversation could be expected at roading decision-maker meetings and community consultation.

Widening the reach of visual tools that assist understanding of Safe System infrastructure treatments also has the potential to create more drive to seek safe system solutions within communities. Taking the road safety conversation to new levels, over time, should influence a reduction in road user injury due to a more normalised safety culture in the community.

The Urban KiwiRAP methodology can be seen as a piece of the strategic jigsaw needed to make the over-arching change in the thinking required for a safe system approach to road safety. It can also be viewed as a fundamental screening tool identifying risk to underpin any sound investment proposal.

For ACC, there is unlikely to be an immediate quantifiable death/serious injury reduction as a direct result of this project. But over the medium term, influencing the way road safety initiatives are prioritised to target the riskiest portions of the roading network will result in a reduction in injury and, therefore, claims to ACC. Based on results achieved by the Transport Agency on the State Highways over the 5 year period, there is potential for ACC to be seeing results by 2020. It is conceivable that ACC could calculate a reduction in claims into the future if infrastructure work programmes were developed using this methodology.

Sector-wide information sharing is critical to getting the paradigm shift needed to ensure a Safe System approach is adopted and the *Safer Journeys* vision of "a safe road system increasingly free of death and serious injury" is delivered. As the road system becomes "increasingly free of death and serious injury", costs to ACC for road user injury would be expected to decrease and levies reduce for the general public.

Conclusion

Adding Value

For ACC, this project is about partnerships and capability/capacity building in the transport sector. It is an opportunity for ACC to improve its perceived value to key partners Police, NZAA, MOT, NZTA, and to build new partnerships with local government by championing innovative methodologies that will provide good safety outcomes.

Urban KiwiRAP is a leverage vehicle to assist in positioning ACC in the area of trust and confidence, improving the attractiveness of partnership with ACC for road network owners and increasing the influence of ACC in the roading infrastructure space.

This project is also an opportunity for ACC to understand more about passive injury prevention projects related to infrastructure, an untapped area with potential benefits for ACC. Advocating for change in funding models and partnering with local authorities to implement projects that might not 'cross the line' in the current investment climate has benefits not just for the local authority and ACC, but also for the wider travelling public – customers of ACC.

ACC has not traditionally worked in the area of assisting with infrastructure improvements. Moving to a position of influence in the planning, prioritisation and funding of infrastructure improvements for safety could be expected to benefit ACC, as a significant shift nationally to prioritised treatment of the highest risk local authority roads will accelerate a reduction in death and serious injury on the road throughout the country.

Next Steps

Of interest are other ways that Urban KiwiRAP is being increasingly used by the pilot project local authorities to assist in transport and district planning. A few of the many examples include:

- A Local Authority updating its Liquor Licensing policies used an alcohol-related crash heat map to identify where crashes were occurring in proximity to licensed premises and assist with its policies relating to alcohol related harm, host responsibility and licensing hours.

- A Local Authority updating its District Plan integrated the risk maps into the traffic impact assessments required for subdivision. Where a subdivision occurred on a high/med high/med risk corridor and had further traffic implications, the subdivider was required to mitigate the traffic issues to medium risk.

- Risk maps have been used for cycleway planning. Examples include shifting a cycle route from a high-risk route to a medium-risk parallel route.

- Local Authority led Road Safety Action Planning processes are referring to Urban KiwiRAP maps and Police are using the information to target enforcement to risk.

- A Local Authority Temporary Traffic Management team is focusing their work site auditing on the higher collective risk routes.

- Risk prioritisation is benefitting business case development for funding of road safety improvements.

- Visual maps are allowing engineering staff to "push back" when community boards or the public advocate for low risk sites to be upgraded.

- Passenger transport route planners are able to identify less "safe" routes for pedestrians and vehicles.

- Network operating contractors and maintenance teams are using the risk maps to target maintenance priorities.

These innovative initiatives were reported from the trial group of four local authorities, with Urban KiwiRAP data being used to assist community decision-making in ways not considered when the analysis was being designed.

Underlying all of these initiatives are the discussions that have arisen from the visual representation of safety risk by Urban KiwiRAP. Cross-organisational teams are talking in a way that was not occurring in the past. Discussions like these have the potential shift the culture of road safety to a true safe system approach to reducing the risk of serious and fatal injury on the road network.

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Use of Improved Evidence on Aboriginal Road Trauma to Develop and Deliver the NSW Aboriginal Road Safety Action Plan

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Transport for NSW

Abstract

This paper details the development of the NSW Aboriginal Road Safety Action Plan and the crash data evidence underpinning its development and delivery.

In 2014 the Centre for Road Safety released the whole-of-Government NSW Aboriginal Road Safety Action Plan. The Action Plan identifies opportunities to harness efforts across Government to reduce Aboriginal road trauma and to achieve other positive outcomes including safer community roads and transport to access social, economic and cultural opportunities. This will be done through improved collaborative action using the Safe Systems approach; a stronger evidence base; promotion of safe and legal driving; providing safe alternative transport options; and improved post-crash response and treatment.

The Action Plan is based on crash and casualty data, practical evidence (accounts from those across Government who work with Aboriginal people) and policy opportunities (mutual interests to improving road safety).

The crash and casualty research evidence has been greatly enhanced by ongoing research to better quantify casualty severities using linked NSW Police and Health records. The linkage study allowed the opportunity to use Aboriginality identifier variables in the Health data, thus better quantifying the extent and characteristics of Aboriginal trauma in road traffic crashes in NSW. Several of the key results from this data linkage are presented in this paper.

In implementing the Action Plan, the enhanced data will help target initiatives to tackle key crash factors, road user groups, locations and demographics to reduce Aboriginal road trauma.

Introduction

This paper will discuss the development of the NSW Aboriginal Road Safety Action Plan 2014-2017 and the concurrent development of crash data evidence that will underpin the focus of its delivery.

In 2014, the NSW Centre for Road Safety (CRS) released the whole-of-Government NSW Aboriginal Road Safety Action Plan. The Action Plan identifies opportunities to harness efforts across Government to reduce Aboriginal road trauma and to achieve other positive outcomes including safer community roads and transport to access social, economic and cultural opportunities. This will be done through improved collaborative action using the Safe Systems approach; a stronger evidence base; promotion of safe and legal driving; providing safe alternative transport options; and improved post-crash response and treatment.

Evidence to develop Action Plan

The Centre for Road Safety's general approach to strategic policy development is to build on the evidence base of crash data. However in 2013, when the Centre for Road Safety commenced development of the NSW Aboriginal Road Safety Action Plan, detailed crash data evidence involving Aboriginal people was not available.

There was limited evidence of Aboriginal road trauma in NSW. Preliminary analysis of coronial records from 2000 to 2009 found that a greater proportion of fatal crashes in NSW involving Aboriginal fatalities on NSW roads involved pedestrians, intoxication, no-restraint use and unlicensed drivers (Roads and Traffic Authority 2010). However, the report noted the possibility of underreporting of Aboriginal status in the coronial and crash records.

Further, a report by the Australian Institute of Health and Welfare found that national fatality rates of car occupants and pedestrians were much higher for Indigenous people compared to non-Indigenous Australians (AIHW 2013).

The Centre for Road Safety recognised that improved data on Aboriginal serious injuries and fatalities is important to enable better targeted policies and programs to reduce road trauma involving Aboriginal people. The development of that knowledge is explained in more detail later in this paper.

However, in the initial absence of detailed crash data, other forms of evidence was sought to inform the early development of the Action Plan. Care was taken to provide some flexibility in the commitments of the Action Plan to enable the serious injury and fatality data, when it became available, to guide policy and program developments.

According to Head (2008) in the contemporary open network approach to policy making, scientific (research) knowledge is only one of three evidence types, with political knowledge and practical implementation knowledge being the others. While the preferred scientific evidence of crash data was being developed, the Centre for Road Safety consulted with representatives from other NSW Government agencies and other Transport for NSW business units with responsibility for Aboriginal policies and programs to understand what they identified were major road safety issues.

Consultation with policy practitioners not only helped provide the practical evidence to guide identification of road safety issues, it provided information about existing programs and resources that could be tapped into, to deliver Aboriginal road safety programs.

The practical evidence also extended to how programs could be designed to be more effective, taking into account the cultural considerations of NSW Aboriginal communities. For example, this process identified the importance of working with Aboriginal community organisations and the potential to use local and regional community road safety champions to help improve road user behaviour.

Inter and intra-agency consultation also identified political insights to align road safety to other strategic directions and commitments of other agencies. Actions to improve Aboriginal road safety have the potential to deliver positive outcomes for other policy objectives. For example, improved roads into Aboriginal communities can make it easier for children to get to school. Also, helping disadvantaged Aboriginal people to get a driver's licence may not only create safer drivers, it could improve access to economic, social and cultural opportunities. It may also reduce prevalence of unlicensed driving and reduce the associated costs for the justice system. The Action Plan identifies partnerships to take advantage of the shared desire to improve road safety, even though the motives for taking action may differ.

Finally, the stakeholder feedback identified the need for better crash data and other scientific evidence. The Action Plan identifies the need to develop improved evidence. Critical to that is the development of fatality and serious injury data which will be used to develop programs better targeted at crash risks and key demographics.

Improving understanding of Aboriginal serious injury in NSW

At the start of this decade the National Road Safety Strategy 2011 to 2020 was developed with the target of reducing fatalities and serious injuries by 30 per cent. Shortly afterwards the NSW Road Safety Strategy 2012 to 2021 was released with the same target of reducing fatalities and serious injuries by 30 per cent. Immediately it became apparent there was a need to identify and report reliable measures of serious injuries in the NSW crash data. A study commissioned by the Centre for Road Safety demonstrated that this information could be obtained through data linkage techniques.

In late 2013 the Centre for Road Safety commenced a project to link CRS crash data with NSW Health data to improve the granularity of the injury data held in the NSW crash database, CrashLink.

One of the first steps in the project was to obtain Ethics and data custodians' approval for the data linkage process and the research questions to be addressed from these data. In mid 2013 a formal application was made to NSW and ACT Health Data Custodians and relevant ethics committees (NSW Population and Health Services Research Ethics Committee, Aboriginal Health and Medical Council Ethics Committee, ACT Health – Human Research Ethics Committee) to request approval for ongoing quarterly data linkage of crash data with the following datasets:

- NSW Admitted Patient Data Collection (APDC)
- NSW Emergency Department Collection (EDDC)
- Mortality data
    - NSW Registry of Births, Deaths and Marriages – Death registrations (RBDM)
    - Australian Bureau of Statistics – NSW deaths (ABS)
- ACT Admitted Patient care (ACT APC) data
- ACT Emergency Department Information System (ACT ED)

The application process was completed in early 2014 and over the course of the next 12 months the data linkage methodology and dataset preparation was developed and refined. Record linkage was carried out by the Centre for Health Record Linkage (CHeReL). Currently crash records in CrashLink from 2005 to 2014 reporting years have been linked to Health data records.

The injury severities derived from the data linkage process were established and defined as follows:

- Fatality – a person who dies within thirty days from injuries received in a road traffic crash
- Serious injury – a person identified in CrashLink (casualty or traffic unit controller) who is matched to hospital admission record on the same day or on the day after a crash and did not die within 30 days of the crash
- Moderate injury – a person identified in CrashLink (casualty or traffic unit controller) who is matched to emergency department presentation record on the same day or on the day after a crash (but not subsequently admitted to hospital)

- Minor / Other injury - a person identified as an injury in CrashLink who is not matched to a hospital admission record or emergency department presentation record within two days of the crash.

An important outcome of the data linkage was the ability to identify and quantify the number of Aboriginal and Torres Strait Islander people involved in road crashes in NSW. To identify Aboriginality among CRS CrashLink records an 'Ever' algorithm was applied. If a person identifies as Aboriginal and/or Torres Islander origin in any records within the APDC or EDDC datasets whether the hospital visit(s) were related to the road trauma or not, they are flagged as being Aboriginal in the linked database.

With the data linkage project being fully operational, CRS is now concentrating on addressing the proposed research questions raised as part of its data linkage application process. Recently CRS conducted an analysis of Aboriginal people involved in NSW road crashes between 2005 and 2013 using the new linked dataset. Some of the key findings of this analysis follow.

During the nine year period 2005 and 2013, there were 3,737 fatalities and 64,249 serious injuries involving road trauma recorded in CrashLink. Of these, 119 involved fatalities of Aboriginal people (3.2%) and 2,681 involved serious injuries (4.2%).

Over this period, both the number of fatalities and serious injuries of Aboriginal people involved in road trauma increased. As the figure 1 shows, the number of fatalities has doubled from 8 in 2005 to 16 in 2013 while the number of serious injuries increased by 34 per cent from 274 in 2005 to 366 in 2013.

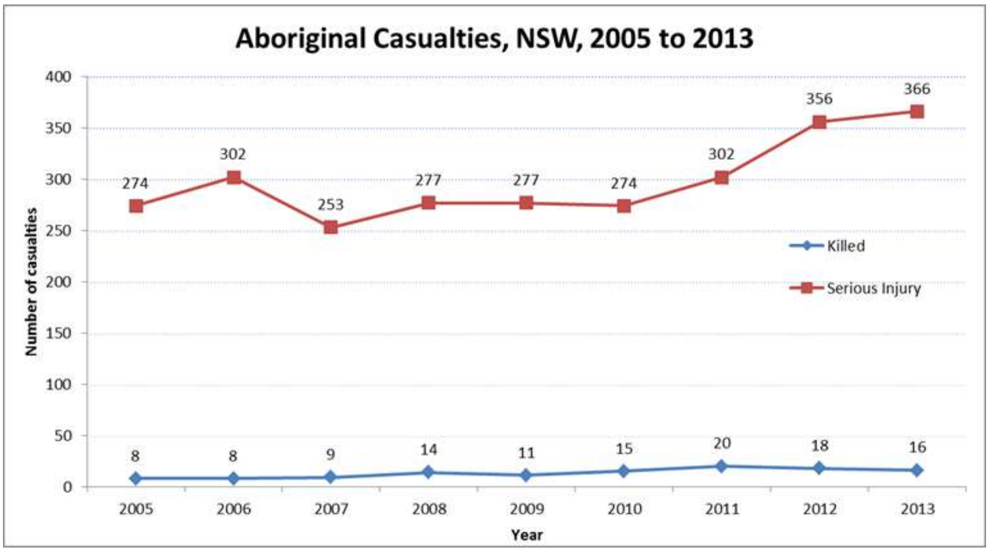

Figure 1: Number of Aboriginal people killed and seriously injured on NSW roads, 2005 to 2013

Aboriginal people are over represented in road trauma in NSW. Over the three year period between 2011 and 2013, Aboriginal people made up five per cent of all those killed and seriously injured, despite only making up 2.9 per cent of the NSW population. Aboriginal fatal injury and serious injury rates (per 100,000 population) are 1.5 times higher than those for non-Aboriginal people.

Further analysis of Aboriginal people killed, seriously injured and moderately injured over the three year period 2011 to 2013 revealed the following:

- over two-thirds (68%) of the casualties occurred in country NSW (that is, outside the Sydney, Newcastle and Wollongong greater conurbation area)

- more than half (57%) of the casualties were males, however the proportion was higher for fatal injuries (72%) and serious injuries (63%). Half the Aboriginal population in NSW is male.
- Aboriginal people aged 15 to 40 years make up 65% of the casualties, yet only represent 38% of the NSW Aboriginal population
- the majority of Aboriginal casualties were drivers (54%) and passengers (22%). Motorcyclists (9%), pedestrians (11%) and pedal cyclists (4%) make up the remainder.
- the most common types of crashes Aboriginal casualties arose from were off-path on straight crashes (24%), off-path on curve crashes (19%) and rear-end crashes (12%).

Enhanced crash data will inform ongoing policy and program development and delivery

The new Aboriginal casualty data is being analysed and will help shape the direction of road safety programs and policies under the Aboriginal Road Safety Action Plan. It is anticipated that the casualty data will be shared with Aboriginal communities and stakeholders, who have the practical implementation and political knowledge, to work together with government to find measures to deliver lasting improvements to Aboriginal road safety.

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Young driver perceived risk and risky driving: Applied theoretical approach to the Fatal Five

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Abstract

Prominent determinants (e.g., age, gender, personality) of young driver (17-25years) engagement in risky driving (the "Fatal 5") are enduring and difficult to change. Therefore, continued research is required to examine psychological variables that can be adapted within young drivers to aid targeted driver interventions to take action to reduce risky driving engagement. Protection motivation theory (PMT), specifically coping and threat appraisal elements, potentially provides additional understanding of young driver decision making in risky driving. Drivers (*N* = 601, 457 females, aged 17-25 years, *M* = 20.03, *SD* = 2.33) holding an Australian driver's license (P1, P2, or Open) anonymously completed a 143-item online survey to measure: 1) PMT for the Fatal 5, 2) perceived risk of driving related behaviours, and 3) the Behaviour of Young Novice Drivers Scale. Using structural equation modelling, the proposed path model of PMT on perceived risk and reported driving engagement showed that perceived risk and coping appraisal were the strongest predictors of reported risky driving engagement. This adaptation of PMT is a novel contribution to the literature as the model helps us to understand what contributes to young driver engagement in risky driving (maladaptive pathway). It also explains why young novice drivers may choose not to engage in risky driving (adaptive pathway). Applications and further implications of the model will be discussed.

Introduction

Determinants of what makes a young driver engage in risky driving have been researched extensively in the road safety and traffic psychology literature. Researching this issue is important as young drivers (aged 16-25 years) are over-represented in national road related death tolls and injuries worldwide (Scott-Parker, Watson, King, & Hyde, 2015; World Health Organization, 2014**)**. Research has identified that this may be due to young drivers' lack of experience and their engagement in risky driving behaviours (e.g., Scott-Parker, Watson, King, & Hyde, 2012a). Many predictors of young driver engagement in risky driving behaviours, such as speeding and drink driving, have been found including: age, gender, and personality variables (e.g., sensation seeking, Cestac, Paran, & Delhomme, 2011; aggression, Constantinou et al., 2011). However, these types of determinants are enduring, being difficult or unable to be changed within young drivers. Therefore, continued research on psychological variables that can be adapted within young drivers is required to help driver inventions that target young drivers' engagement in risky driving behaviours.

Preventing and reducing motor vehicle crashes (MVCs) involving drivers of all age groups is important for governments, policy makers, and researchers. The focus on young drivers arises from the factors discussed above that increase young drivers' MVC involvement risk. Therefore research on young drivers' risk perception and reported engagement in risky driving is vital to understanding how and why young drivers choose whether to engage in risky driving behaviours. A social cognitive model, protection motivation theory (PMT) has two primary cognitive mediating processes in decision making – threat appraisal, and coping appraisal (Floyd, Prentice-Dunn, & Rogers, 2000; Rogers, 1975, 1983). Threat appraisal has three components: *severity, vulnerability,* and *rewards.* Severity and vulnerability operate to increase protective motivation; however, these factors are influenced by the possible rewarding advantages of performing the maladaptive health behaviour (in this case, risky driving), which will decrease threat appraisal's overall protective motivation towards the behaviour. Coping appraisal also has three components: *response efficacy, self-efficacy,* and *response costs.* Higher effectiveness and confidence in performing adaptive behaviours increases protective motivation, unless the last component, the response costs experienced by performing the adaptive behaviour, are too great, which decreases coping appraisal's overall protective motivation towards the behaviour (Armitage & Conner, 2000). Within traffic psychology PMT has been successfully applied in exploring drunk driving (Cismaru, Lawack, & Markewich, 2009; Greening & Stoppelbein, 2000; Murgraff, White, & Phillips, 1999), and effectiveness of anti-speeding messages (Glendon & Walker, 2013).

PMT can be used to represent a driver's judgement of the probability of a harmful event happening to them (e.g., an MVC – resulting from dangerous driving behaviours). The probability that a driver will perform a protective, rather than a maladaptive behaviour, will be greater if the driver identifies with a stronger response efficacy, has a higher self-efficacy, and perceives fewer costs in performing the adaptive behaviour. Engaging in maladaptive driving behaviours is more likely if the driver has positive views about the rewards associated with the behaviour, and perceives low vulnerability and severity of the behaviour (Floyd et al., 2000). From these components as independent factors, higher coping appraisal and higher threat appraisal would be predicted to decrease a driver's engagement in risky driving behaviours.

The aim of this study was to test an application of PMT on young driver decision making, including their perceived risk, and reported engagement in risky driving behaviours. It was predicted that the PMT model would provide a basis for exploring young and inexperienced drivers' threat and coping appraisals in respect of risky driving behaviours (e.g., the Fatal 5) that may result in MVCs. Specifically, it was hypothesised that higher coping appraisal and higher driver perceived risk would decrease reported risky driving engagement. Higher threat appraisal was predicted to increase driver perceived risk, and to decrease reported risky driving engagement.

Method

Participants

Participants (N = 601, 457 females, aged 17-25 years, M = 20.03, SD = 2.33) held an Australian driver's license (P1, P2, or Open), and drove a car regularly (excluding moped, motorbike, truck, bus, van, etc.). One-hundred-and-seventy-six (29.3%) held a Provisional 1 (P1) license, 231 (38.4%) a Provisional 2 (P2) license, and 194 (32.3%) held an open license. Survey participants reported driving for a mean of 211.68 km (SD = 176.44) a week.

Measures

Participants anonymously completed a 143-item online survey. In addition to demographic items (e.g., age, sex, license type), scales measured perceived risk, reported risky driving engagement, and protection motivation components. Perceived risk focused on cognitive aspects of risk perception, aversion to risk taking (perceived danger) for the driving behaviour (e.g., drink driving, speeding), and perception of the likelihood of an MVC occurring to the participant (30 items, α =.91).

From Scott-Parker et al.'s (2012b) revised Behaviour of Young Novice Drivers Scale (BYNDS 36 items, α = .90), the transient violations (12 items, α = .89), and fixed violations (6 items, α = .80) subscales were used to measure reported risky driving engagement (total 18 items, α = .88).

A PMT driver scale was created based on previous research (e.g., Greening & Stoppelbein, 2000; Murgraff et al., 1999) where items were designed to measure threat appraisal and coping appraisal in two subscales. Each subscale contained three facets – severity, vulnerability, and rewards items formed the threat appraisal subscale, while response efficacy, self-efficacy, and response costs items formed the coping appraisal subscale. An initial 90 items were reduced through confirmatory factor analysis to identify the best item pool that represented the Fatal 5 driving behaviours within the PMT framework. This resulted in a final 30-item measure (α = .83).

Procedure

The online survey was created using the Lime Survey tool. The hyperlink to the online survey was advertised using Griffith University's e-news-sheet Volunteer for Important Research Projects and the School of Applied Psychology subject pool. The survey was available online for three months. Drivers aged 17 to 25 who held an Australian driver's license were invited to participate.

Results

After the measurement model confirmed the created scales, a path analysis was conducted using the final versions of the measured variables. Results supported the hypothesised model with fit statistics for the path model being, $\chi^2 = .02(1)$, $p = .904$, CMIN/df = .02, AGFI = 1.000, CFI = 1.000, RMSEA = .00 CIs = .00-.05, indicating a good data fit for the hypothesised model. In fact, threat appraisal completely mediated coping appraisal's direct effect to driver perceived risk, β = -.39, $t = -10.20$, $p < .001$, to zero. Coping appraisal operated indirectly through threat appraisal on driver perceived risk. Figure 1 shows the final recursive model.

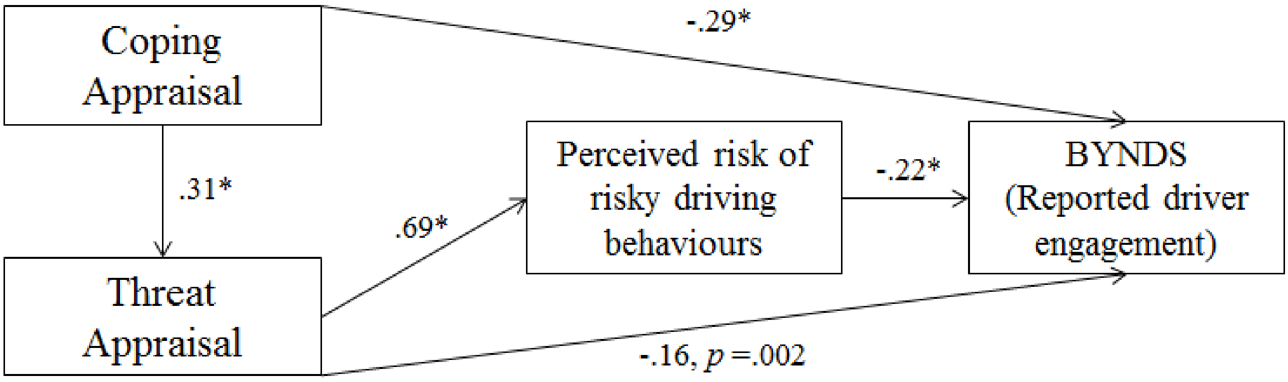

Figure 1. Path diagram showing effects of PMT variables on driver perceived risk and reported engagement in risky driving behaviours (N = 601). Note: * p<.001.

Discussion

The results supported both hypotheses. From the beta weights shown in Figure 1, it can be concluded that coping appraisal, threat appraisal, and driver perceived risk directly influenced reported engagement in risky driving behaviours (measured by the BYNDS subscales). The direction and significance of the regression coefficients indicated that higher coping appraisal, which was the strongest predictor, threat appraisal, and driver perceived risk decreased reported risky driving engagement. This indicated that higher responsiveness to driver vulnerability and severity of the risky driving behaviours, and higher perceived response efficacy and self- efficacy in applying the adaptive behavioural response, decreased respondents' reported engagement in risky driving behaviours. While response costs and rewards associated with the risky driving behaviours did not significantly decrease protection motivation, their influence cannot be dismissed and further research on the individual components of coping and threat appraisal need to be further examined. This is an important highlight as the six components of coping and threat appraisal might be expected to improve predictions about the decision process of young drivers who choose to engage in risky driving behaviours, and those who do not.

The fully mediated effect of coping appraisal on driver perceived risk indicated that coping appraisal had no unique effect on driver perceived risk, as the relationship was non-significant once threat appraisal was accounted for. This effect is to be expected, given that threat first needs to be perceived before coping mechanisms are activated. The highest beta weight was for the relationship between threat appraisal and driver perceived risk, which was expected due to some shared variance between these two variables, both being created from similar constructs (threat appraisal's vulnerability and severity; driver perceived risk aversion and likelihood of negative consequences).

As preliminary results have found that PMT variables can influence young drivers' reported perceived risk and risky driving engagement, further research could usefully be conducted using PMT variables to examine the adaptive and maladaptive pathways in risky driving decision making. Our results indicate that when developing and evaluating young driver interventions, focus is also required on factors that contribute to young drivers engaging in non-risky behaviours, as well as factors that aid decision making processes that lead to not choosing to engage in risky driving behaviours. From this, it is clear that PMT could help in further understanding the young driver decision making process in respect of engaging in risky driving behaviours as a developing application in road safety.

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A road safety risk prediction methodology for low volume rural roads

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Abstract

The roads of New Zealand's Eastern Bay of Plenty region have relatively low vehicle volumes and experience a number of rural road safety issues, including inappropriate speed, the use of drugs and alcohol, low levels of restraint use and young/inexperienced drivers. Over half of all rural crashes are loss-of-control crashes on curves. Due to low network traffic volumes, crashes tend to be sporadic and difficult to predict using risk assessment techniques that rely on crash histories.

This paper introduces a new risk prediction methodology that identifies high-risk curves independent of crash history. Using geospatial data and innovative analysis techniques, existing methodologies for identifying curves and calculating vehicle operating speeds were modelled and automated to undertake a network-wide assessment of high risk curves.

The new methodology extracted and classified almost 7000 curves across 1500km of road network. When compared to the location of loss-of-control crashes, it was found that 66.6% of crashes occurred on 20.3% of curves classified as 'high risk' in at least one direction. These results have been shared with road controlling authorities and will support prioritised road safety improvements targeting high risk curves.

This methodology is the first network screening tool that has been specifically developed to address road safety risk in low volume rural areas in New Zealand or Australia. The methodology demonstrates how existing research into vehicle operating speed behaviour can be applied to identify high risk road elements and support targeted improvements that have the potential to significantly reduce road safety risk.

Introduction

Safer Journeys, New Zealand's Road Safety Strategy 2010-20 has a vision to provide a safe road system increasingly free of death and serious injury (Ministry of Transport, 2010). This Strategy adopts a safe system approach to road safety focused on creating safe roads, safe speeds, safe vehicles and safe road use. These four safe system pillars need to come together if the New Zealand Government's vision for road safety is to be achieved.

Safe system signature projects are identified in the Safer Journeys Action Plan 2013-2015 (New Zealand Transport Agency [NZTA], 2013) as exemplar projects that adopt a complete safe system approach to road safety. Safe systems signature projects provide a platform for trialling innovative approaches and treatments across the four safe system pillars.

The Eastern Bay of Plenty region (Figure 1) was identified as a candidate for a safe systems signature project as it is a region with significant rural road safety issues; particularly inappropriate speed, use of alcohol/drugs, poor restraint use and inexperienced drivers. The scope of the project includes rural State highways and local roads. Most Eastern Bay of Plenty roads are low volume remote roads, where crashes tend to be sporadic and difficult to predict using reactive crash prediction models. Therefore a new approach to assessing road risk, independent of crash history, was required.

Abley Transportation Consultants was commissioned by the New Zealand Transport Agency (the Transport Agency) to develop a risk prediction model and mapping interface "SignatureNET" to support the delivery of this signature project. This included building a vehicle speed model to identify high risk curves, assessing road risk using the urban KiwiRAP risk mapping methodology (Brodie et al., 2013), and applying rural road risk prediction models.

Figure 1. Eastern Bay of Plenty locality map

Methodology

Many rural road crashes in Eastern Bay of Plenty occur on curves (57.9% of all fatal and serious rural road crashes 2004-2013) (NZTA, 2014). Due to the remote nature of the region's roads, fatal and serious crashes tend to occur on parts of the network where high-severity crashes have not occurred in the recent past. In these areas, relying on crash history alone to predict where future crashes will occur is unreliable. A new methodology that could identify and assess the risk of all the curves on the network that was independent of crash history was developed.

The Austroads (2009) operating speed model for rural roads provides a procedure for calculating speeds along road sections based on the geometric features of the road. Using calculated speeds and horizontal curve radii, the model allows users to assess the design limit of curves.

With 1500 km of rural road, manually assessing the risk of each curve in the Eastern Bay of Plenty region using the Austroads model would be time-consuming and cost-prohibitive. As the inputs to the Austroads operating speed model are available in a spatial format, the model was therefore automated using a new Geographic Information Systems (GIS) methodology. This included the development of GIS models that identify curves, predict vehicle operating speeds along road corridors, and assess curve risk using approach speeds and radius (Harris & Durdin, 2015). This methodology is discussed, in brief, below.

Curve identification

The first step in speed modelling methodology is to identify curves using a high quality road centreline and a methodology adapted from Cenek et al. (2011). The spatial road dataset used in this methodology closely matched the actual centreline of the road. Using GIS linear referencing tools, the road centreline was divided into 10m sections and the rolling 30m average radius calculated for each arc section.

Discrete curve sections were extracted by combining road segments where:

(a) the radius was less than 800m;

(b) at least one 10m section had a radius of 500m or less; and

(c) the apex (direction) of the curve did not change.

Contiguous 10m sections of road that met these criteria were dissolved into a single curved segment, with the radius (m) of the curve defined as the minimum radius across all the sections that make up the curve. The calculated curve radii represents a mid-road curvature value (rather than separate curve radii values for each lane or direction), noting that there are no divided carriageway roads in the Eastern Bay of Plenty region.

Speed modelling

The Austroads (2009) operating speed model predicts the operating (85th percentile) speed of cars travelling in each direction along a section of rural road. The model mimics the real-world behaviour of drivers based on a large number of car vehicle observations. As such, the model only applies to cars and cannot be used to predict the operating speeds of other types of vehicle.

Once curves had been identified (see above), each road corridor was divided sequentially into a series of curves with known radii, and straights with known lengths. Speeds were then modelled along the road centreline in both directions. Sections of road with curves of a similar radius separated by short straights (less than or equal to 200m) were identified as discrete sections with an operating speed identified within a narrow range of values (minimum and maximum operating speeds). When drivers travel through a series of curves with a similar radii, their speeds stabilise to a level they feel comfortable with (Austroads, 2009). Section operating speeds for single, isolated curves were also calculated.

Working along the road corridor, speed behaviour was modelled as either:

(a) *Acceleration* on straights longer than 200m, or on curves where the approach speed is less than the operating speed of the curve.

(b) *Speed maintenance* on straights less than 200m, or where the speed falls within the section operating speed range.

(c) *Deceleration* on curves where the approach speed is higher than the operating speed for the curve (or series of curves).

Rates of acceleration and deceleration were modelled using the methodology in Austroads (2009) (Figures 2 and 3). Extrapolation of values was required to estimate some acceleration and deceleration outputs, including acceleration for straights longer than 1000m (Figure 2) and deceleration where curve approach speeds are less than 60 km/h (Figure 3).

The exit speed at the end of each curve or straight is applied as the approach speed for the following section of road. For each curve where deceleration is modelled, the design limit is identified as either out-of-context (unacceptable or undesirable) or within context (desirable) (Figure 3). Curves where no deceleration is modelled are also considered to be ‘within limit’.

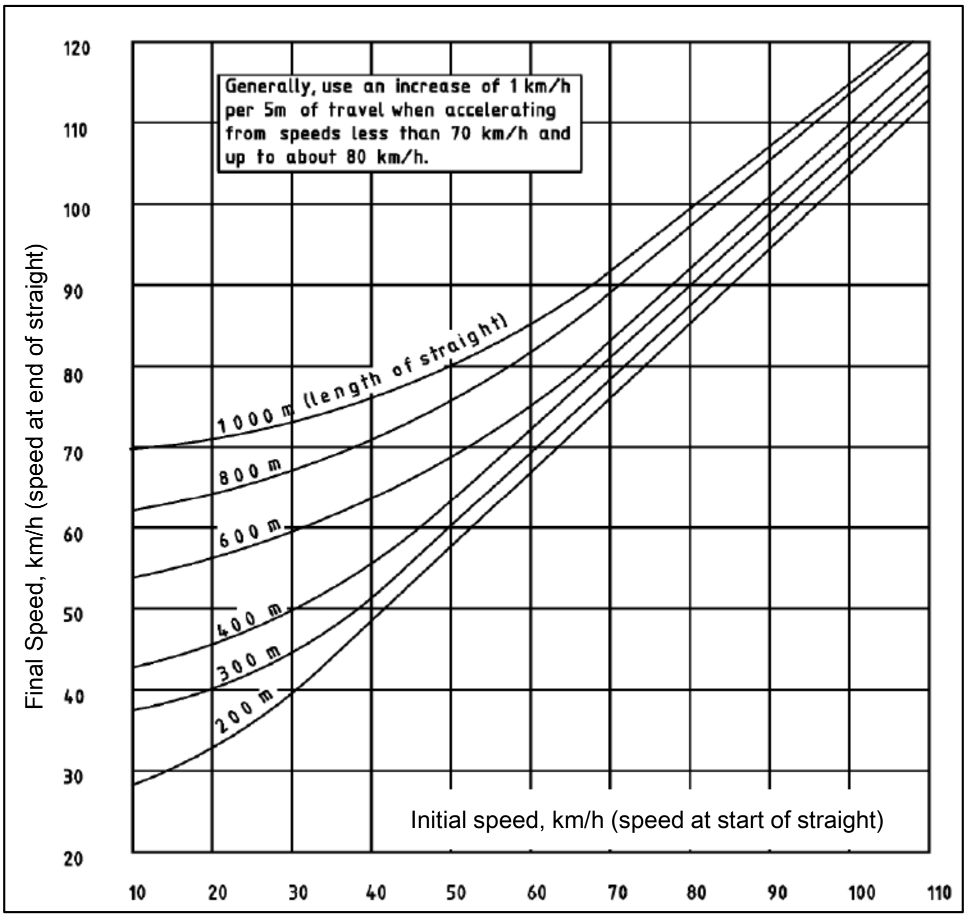

Figure 2. Acceleration on straights (source: Austroads, 2009)

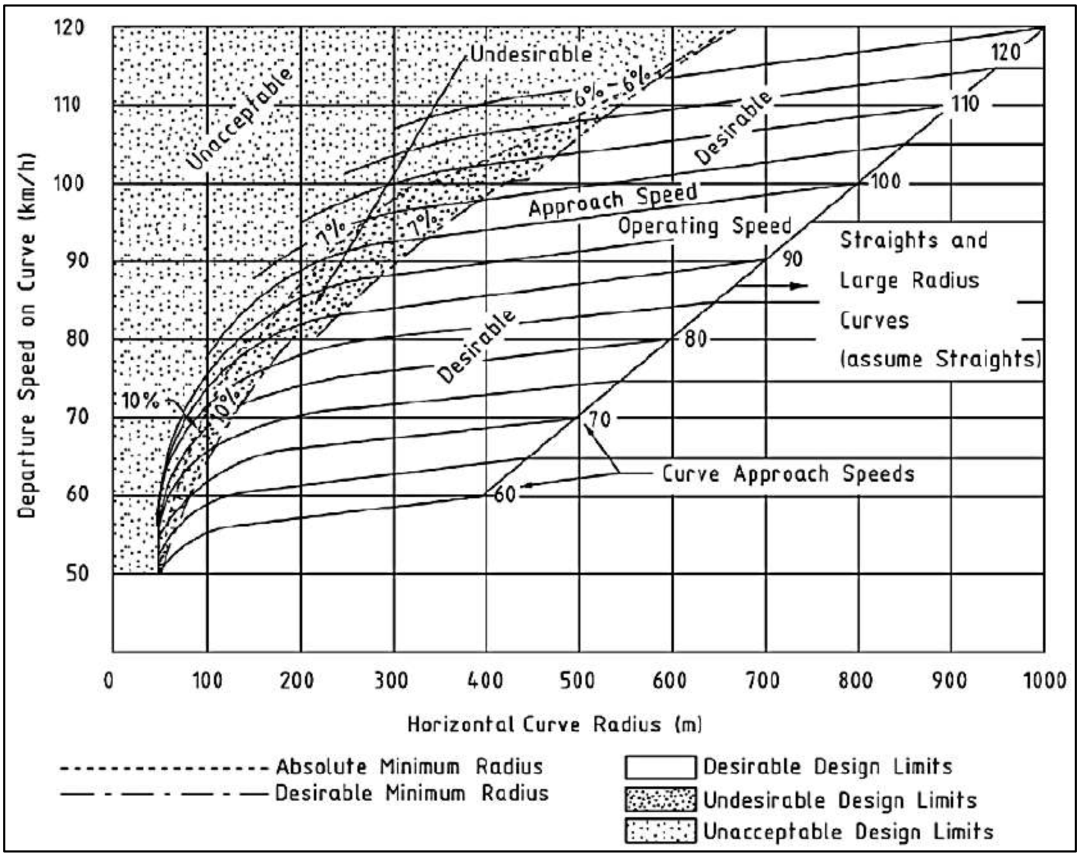

Figure 3. Deceleration on curves and design limits (source: Austroads, 2009)

Results

The curve identification methodology recognised 6,985 curves across the Eastern Bay of Plenty region. Each curve was classified by design limit (in both directions) according to the Austroads speed model (Figure 3). The number of curves identified by category are displayed in Table 1. Where curves were classified differently in opposing directions, the worst (most out-of-context) classification has been applied. For example, a curve that is 'undesirable' in one direction but 'within limit' in the reverse direction would be categorised as 'undesirable'.

Table 1. Eastern Bay of Plenty curve categorisation

Curve Category	Total Curves	% of all Curves
Unacceptable	600	8.6%
Undesirable	815	11.7%
Desirable	941	13.5%
Within Limit	4629	66.3%

Because the curve identification methodology developed for this project was a new and untested, the results were compared against an existing Transport Agency curve dataset for the state highway network in the Eastern Bay of Plenty. The state highway curve dataset is based on horizontal curvature data collected in the field as part of the Transport Agency's annual high speed surveys (Cenek et al., 2011).

The new methodology identified the location of 96.8% of curves in the state highway dataset, with a visible correlation between curve radii values (Figure 4). The two datasets met the assumptions required for linear regression, with 82% of calculated curve radii values within 20% of the Transport Agency's curve radii values. The degree of scatter between the two datasets, particularly for large-radius curves, is primarily attributed to the different collection methods. The state highway dataset is collected in-field using lane-based radii, whereas the operating speed model methodology relies on radii values calculated from the centreline. Extreme outlier values are more likely to reflect errors in the geometry and topology of road centreline dataset.

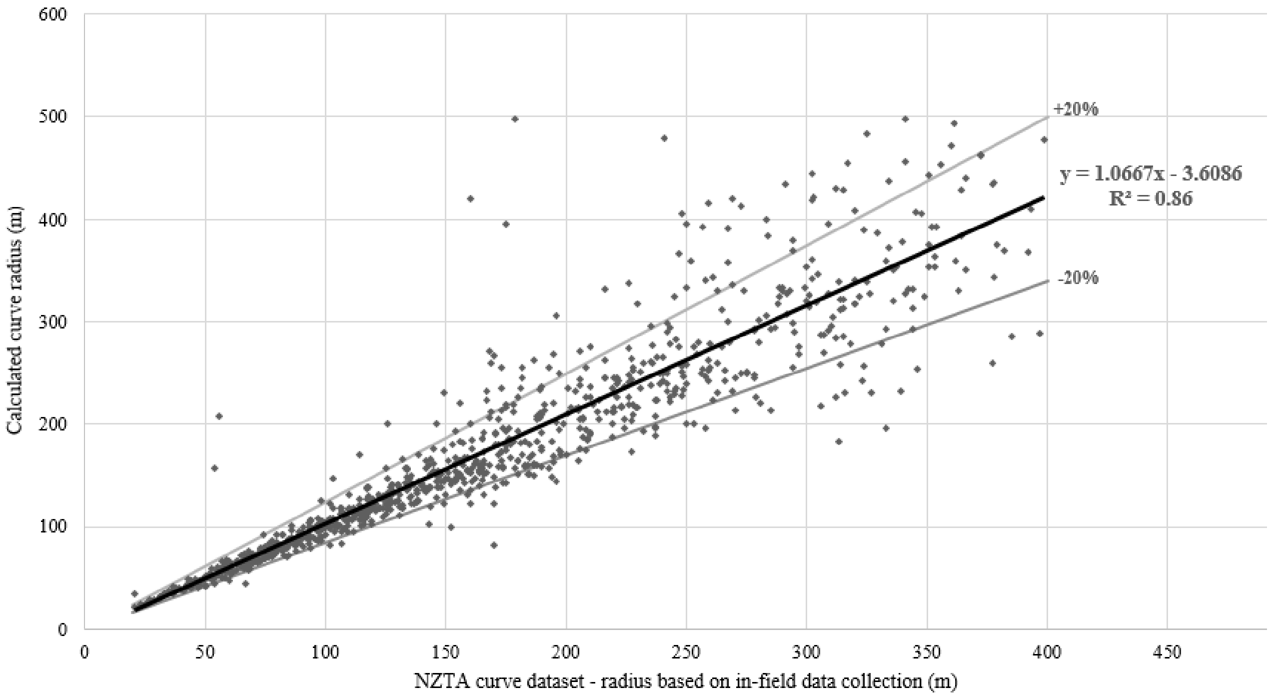

Figure 4. Comparison of calculated curve radii against NZTA out-of-context dataset

The results of the curve analysis were delivered through a mapping website ("SignatureNET"), which displayed the risk metrics alongside contextual road safety data including administrative boundaries and crash locations (Figure 5).

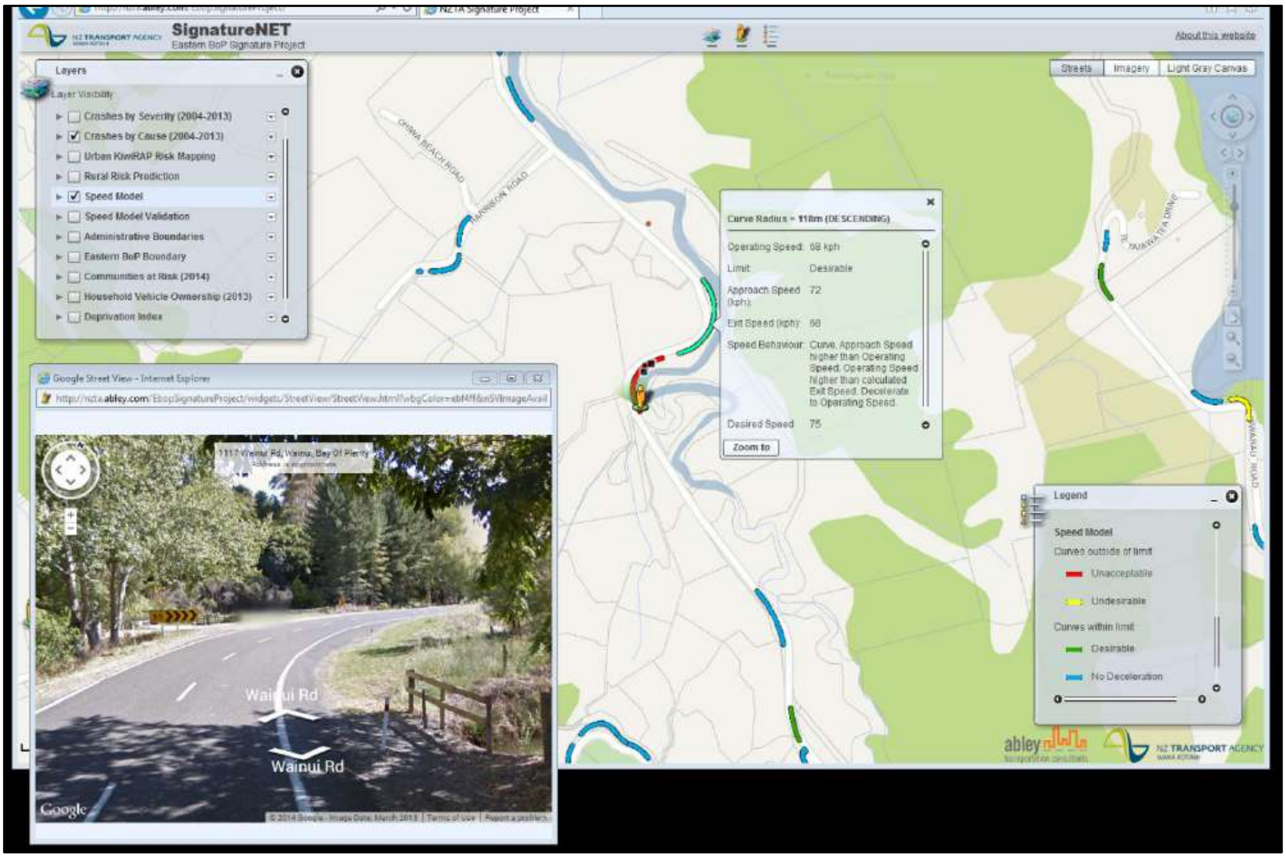

Figure 5. SignatureNET mapping website screenshot

Correlation between curve category and loss-of-control crashes

Further analysis was undertaken to identify the number and percentage of loss-of-control crashes by curve category. For this comparison, 10-years of crash data (2004-2013) was selected from New Zealand's Crash Analysis System (CAS) (NZTA, 2014a). For the purposes of this analysis, loss-of-control crashes were defined as those with movement code 'BF' (head on - lost control on curve), 'DA' (lost control turning right) or 'DB' (lost control turning left) in CAS (NZTA, 2014b).

In the 10-year period selected, there were 589 loss-of-control crashes on the curves categorised using the curve risk assessment methodology. The number and percentage of loss-of-control crashes by curve category are presented in Table 2.

Table 2. Eastern Bay of Plenty loss-of-control crashes by curve category

Curve Category	Total LOC Crashes	% of all LOC Crashes
Unacceptable	226	38.4%
Undesirable	166	28.2%
Desirable	64	10.9%
Within Limit	133	22.6%

The results show that two thirds (66.6%) of all loss-of-control crashes occur on out-of-context curves i.e. those identified as 'unacceptable or 'undesirable'. This is a particularly important finding as it means road controlling authorities in the Eastern Bay of Plenty can target efforts on 20.3% of all curves where 66.6% of all loss-of-control crashes occur.

Further analysis and model validation

Since the first development of the operating speed model for the Eastern Bay of Plenty, the operating speed model has been applied to the Top of the South region of New Zealand - the area encompassed by the South Island local authority districts of Marlborough, Tasman and Nelson City. It includes some 3382 km of rural roads, which is much larger than the Eastern Bay of Plenty region (approximately 1500 km).

The operating speed model identified a total of 21,158 curves in the Top of the South region. The results of the curve classification are displayed in Table 5, showing that the proportion of curves in each classification in the Top of the South region mirrored the Eastern Bay of Plenty region (Table 3) very closely.

Table 3. Top of the South curve categorisation

Curve Category	Total Curves	% of all Curves
Unacceptable	1772	8.4%
Undesirable	2215	10.5%
Desirable	2345	11.8%
Within Limit	14826	70.1%

Analysis of loss-of-control crashes against curve category was also undertaken for the Top of the South region, identifying that 55.8% of all loss-of-control crashes occurred at 18.9% of curves identified as out-of-context (‘unacceptable’ or ‘undesirable’) (Table 4). This result is similar to the analysis of the Eastern Bay of Plenty region, although the correlation is not as pronounced.

Table 4. Top of the South loss-of-control crashes by curve category

Curve Category	Total LOC Crashes	% of all LOC Crashes
Unacceptable	360	32.3%
Undesirable	262	23.5%
Desirable	135	12.1%
Within Limit	359	32.2%

The Eastern Bay of Plenty and Top of the South data were combined so the relationship between curve categorisation and loss-of-control crashes could be better understood (Figure 6). This figure shows there is a strong relationship between curve category and loss-of-control crashes. The relationship indicates that focusing road safety improvement efforts on out-of-context curves is targeting to risk.

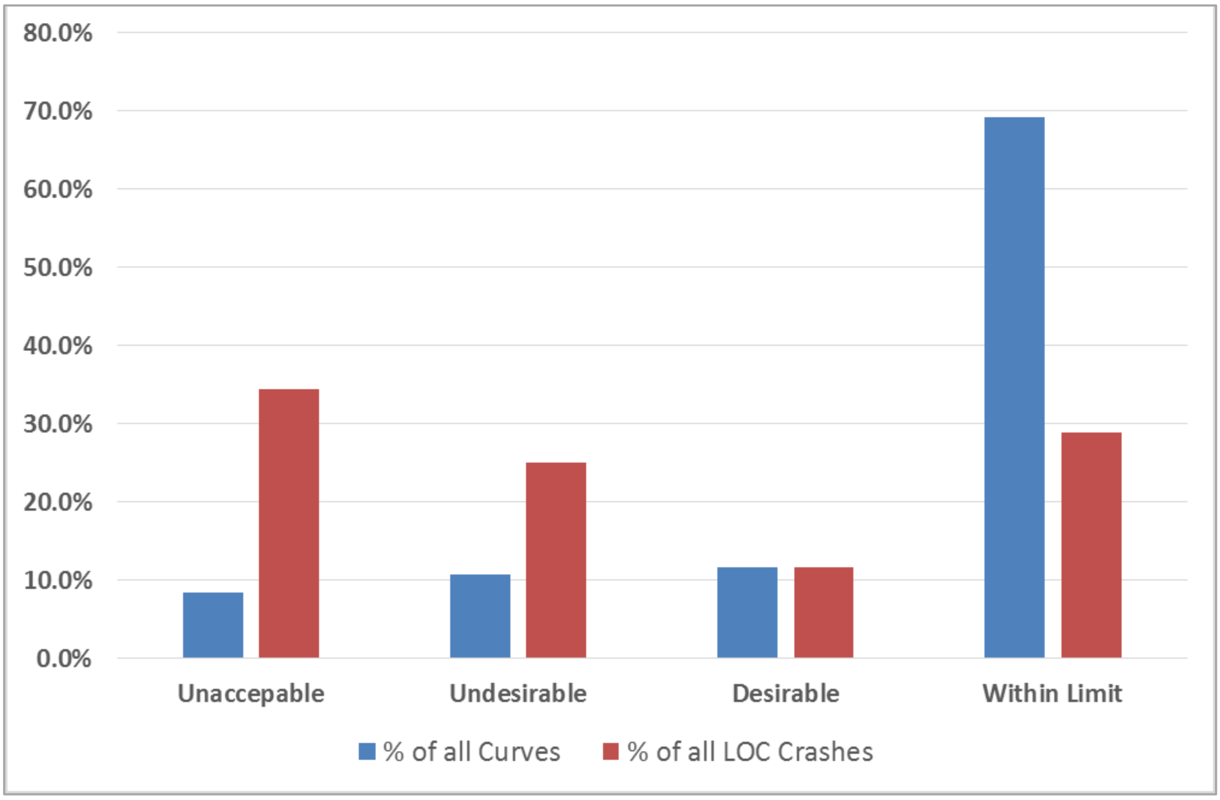

Figure 6. Graph demonstrating the relationship between curve category and the location of loss-of-control crashes

Discussion

The methodology presented in this paper has been well-received by all the agencies involved in the delivery of the Eastern Bay of Plenty safe systems signature project. The curve risk data and SignatureNET web viewer is now available to all the local road controlling authorities to assist them in identifying and prioritising road safety interventions targeting loss-of-control crashes on curves.

Current applications

The curve assessment and automated operating speed model is currently being rolled-out across other locations in New Zealand.

Informing speed management decisions

The Transport Agency has developed a process for identifying parts of the state highway road network for speed management interventions based on road safety risk. Potential interventions include targeted enforcement, reducing speed limits, or upgrading parts of the road network to reduce the frequency and severity of crashes at current operating speeds. To determine and prioritise appropriate intervention strategies, the operating speed model was applied across the high speed state highway network to determine: (a) operating speeds under current speed limits; and (b) operating speeds under the identified safe and appropriate speed limits, noting that speed limit is a factor in determining the maximum (desired) speed of a road (Austroads, 2009; Harris & Durdin, 2015).

The different operating speeds are then being used to estimate the potential for death and serious injury (DSi) savings by using Nilsson’s Power Model which connects changes in traffic speeds with changes in road crashes at various levels of injury severity using a power relationship (Nilsson, as cited in Cameron & Elvik, 2008). Sections of state highway that exhibit little or no speed reduction are considered to be 'self-explaining' as the geometry and terrain of the road naturally prevents drivers from achieving higher speeds. Conversely sections with extreme differences when comparing the current operating speeds and the safe and appropriate operating speed are generally straight roads where enforcement or engineering improvements may be more appropriate, depending on potential DSi savings and the functional classification of the corridor.

Training safety practitioners

As noted earlier, the methodology has been extended to the Top of the South region in New Zealand for exercises in the annual Safe Systems Engineering Workshop. The outputs were presented in a web viewer and combined with Urban KiwiRAP risk profiles for the region delivered as part of an Accident Compensation Corporation (ACC) funded road safety initiative. The web viewer was used as learning media to introduce Safe Systems Engineering Workshop attendees to the use of network screening tools to assist with the identification of road safety issues across the region. By considering different risk metrics alongside one another and in combination with crash data, practitioners were able to identify potential factors contributing to high-risk locations and formulate responses at a desktop level prior to physically investigating sites.

Limitations and future enhancements

The speed modelling and curve risk assessment methodology is of greatest value to road safety practitioners where it is used as a network screening tool. The methodology should be applied with care when considering individual curves. Site-specific factors such as roadside hazards should be taken into account when identifying or prioritising curve treatments. For this reason, the SignatureNET web viewer included aerial imagery basemaps, Google Street View and other contextual data to support users in undertaking desktop reviews.

During the development and roll-out of the methodology, a number of further enhancements were suggested and are being explored. These include:

(a) Enhancing the speed model by exploring the relationship between curve risk category, road surface type, carriageway width and actual road safety performance.

(b) Exploring the relationship between curve risk category, KiwiRAP star rating and the road safety performance of state highways.

(c) Enhancing the speed model by comparing calculated operating speeds against known operating speeds, for example data collected using GPS devices.

(d) Exploring the feasibility of using high-resolution elevation data collected using LiDAR, (if available) to calculate superelevation and vertical curvature and incorporate these factors into the curve risk assessment models.

Conclusion

The operating speed model and high risk curve assessment methodology demonstrate that innovative assessment methods and tools can be developed within a safe system signature project environment. Current applications of this methodology in New Zealand demonstrate the potential of this methodology in supporting the safe system philosophy, including the identification of high risk curves for targeted safety investigation and treatment (Eastern Bay of Plenty), supporting the development of the New Zealand Transport Agency's Speed Management Guide, and being used as training media for Safe Systems Engineering Workshops. The curve identification and analysis techniques presented in this paper will be of particular interest to any road controlling authorities wanting to reduce loss-of-control crashes on rural roads.

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Road Safety Audits in Australia 20 Years after Inception: Examination of Practical Issues and Limitations

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Abstract

Industry surveys examined road safety auditing in practice in Australia, 20 years on from its inception. This paper summarises the findings of the 33 qualitative surveys of 59 people. The target attribute of participants was a high level of experience undertaking or responding to road safety audits. Participants were from Vicroads, Councils, engineering consultancies, construction companies, and design companies. Interviews occurred in metro and regional Victoria, and in Brisbane. Key discussion topics were training, accreditation, and quality. Recommendations have been provided based on the findings. Key recommendations are: a generic, systematic and centralised reporting and management system; a model accreditation system; and, an industry group / organisation.

Introduction

A generation has passed, and road safety auditing has matured in Australia. It commenced in the mid-1990s just after establishment in the U.K. It has become a well-established safety tool forming part of the road design / construction landscape and its basic meaning is widely understood within the road design / traffic and road safety engineering industry. Although road safety audits have become increasingly entrenched in road design / construction, very little has changed in 20 years in relation to 'road safety audit infrastructure'. For example: training; accreditation; and standard contract clauses.

Key aspects of design, project management and the industry in general have changed in ways that affect road safety auditing markedly. For example: the legal landscape; skills-retention within road authorities; skills shift from public to private sectors; risk management; and quantity of available auditors. Also, the process is essentially a review based largely on subjectivity and experience, yet there is scant critical examination of the road safety audit process and industry. As such, important issues such as quality, timing, consistency, accreditation, should be critically examined.

Informal feedback from people within the industry to the author has triggered this more in-depth survey into the 'in-practice' issues with road safety audits. This was done by targeting a number of key people highly experienced in the industry through lengthy individual or group discussions.

Objectives of the qualitative surveys

- Understand the general positives and problems both from an auditor and client perspective.
- Examine the issues with reference to the first principles of a road safety audit, in particular quality and value.
- Formulate recommendations for the Australian context.

Austroads Project T1774 Revision of Guide to Road Safety Part 6 – Road Safety Audit

Austroads is currently undertaking Project T1774 'Revision of Guide to Road Safety Part 6 – Road Safety Audit', with its interim report published September 2013. The Austroads research was Australia-wide, and the stated objectives are:

- "alignment of current road safety audit processes and practice with a Safe System approach to road safety
- harmonisation of road safety audit processes across Australian and New Zealand jurisdictions
- production of a clear, concise and easy-to-use guide for practitioners." [1]

This survey work and the Austroads project have overlaps in scope, in particular with accreditation, training, risk ratings, variation to the standard process, and recommendations. However, the surveys and participant-types for this work differed by having the main focus on the first principles issues of *quality* and *value* from real-life practitioners able to speak freely ('off the record').

Survey Methodology

Participant Selection

Participants were selected based on the author's knowledge of the person's participation in road safety audits from a client's perspective, a practitioner's perspective, or both. The author's knowledge of these people is based on eleven years working full time in the road safety audit field (a relatively small niche area of road design / road safety). A secondary consideration was the level of access to and availability of participants. Many participants had practiced or lived in rural or regional areas, however, there was a general urban bias in the survey sessions and participant origins.

Surveys

The surveys were conducted between July 2014 and April 2015. The duration was typically 1-2 hours. At the start of interviews, participants were given a topic prompt-list as a guide, mostly compiled from previous sessions, and advised that they should feel free to raise any topic on any tangent relating to road safety auditing in practice. Topics were: accreditation, quality, independence, audit timing, client understanding of audits, report structure / content / language, detail and wording of recommendations, risk ratings, administration, training, signing-off, and predictions.

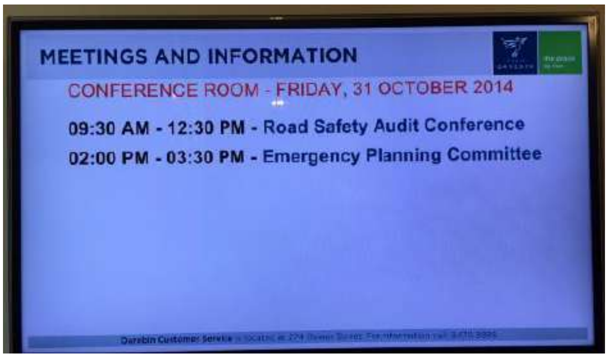

Photo 1 and 2: A discussion session in November 2014

Summarising and presenting the information

All survey feedback points were inserted into tables under topic headings. The feedback under each topic heading was reviewed, with the dominant views extracted. Ideas/comments that were particularly different or thought provoking were extracted as individual quotes. Quotes have been used throughout the paper without referencing the specific source, as agreed with participants, for professional privacy.

Scope

As this was private work with no funding, it attempted to examine the most important issues directly from some of the most experienced and respected practitioners in the road safety audit environment from the public and private sectors. The surveys were intended to initiate broader discussions within the industry, and also led to an extended paper in the form of a whitepaper which was disseminated into the industry in July 2015. The emphasis of the surveys was on Victoria, due to the author’s location.

Summary of key findings from surveys

- Some limited procedural/overview training is compulsory (2-day overview workshop), however technical road safety audit training does not exist in Australia.
- Accreditation systems have a very low standard to become a ‘senior road safety auditor’.
- Some who engage or respond to road safety audits have a poor understanding of what a road safety audit is, and what it is not.
- There is no quality process for ensuring the client / designer understands the auditor’s issue, either in part (the finding) or in full (the recommendation in the context of the finding).
- Audits are commonly triggered by a variety of reasons other than the guidance of a standard policy, and are being used for unorthodox purposes (outside of classical definitions in the Austroads guide).
- Quality assurance could remain as ‘market-driven’ through reputation, or move into a more professional realm with external validation, standards, and peer review.
- Wide range of views on the meaning of ‘independence’, and on report structure, language, content, wording, strength and specificity of recommendations. This reflects the relatively open guidelines.

- Road authorities tend to prefer a high level guidance in recommendations when compared to designers and consultants who prefer detailed recommendations through text and images.
- Some design audits are still not well timed to add real value to the project.
- Some standard audit specifications in road authority contracts are out of date with current practice.

Expanded findings from key topics

How are road safety audits triggered?

Road safety audits are mandated within Vicroads through a road safety policy but are also routinely procured through the discretion of individual engineers. One Vicroads employee "…we frequently use audits as a tool to get a contractor to do what they are supposed to. Contractors are reluctant to listen to experienced [road authority] staff, however are more likely to listen to something an auditor says".

Local councils tend to carry out internal safety checks and only procure formal road safety audits on Vicroads funded projects, blackspot funding applications or local issue disputes. Design and construction companies stated that they carry out non-mandatory road safety audits at their own initiative and cost when the project is large, complex or specialised.

Variation to standard audit types

They are frequently commissioned for reasons other than those nominated in the *Austroads Guide to Road Safety; Guide to Road Safety Audit Chapter 6*. The following alternative uses were described:

- To compare one design to another (especially feasibility stage audits).
- To arbitrate between disputing parties or an alternative opinion.
- A reactive crash-countermeasure tool rather than a proactive crash-minimisation tool (especially existing conditions and construction traffic management stage audits).
- A literature review on a specialised topic (e.g. a road safety barrier).
- A speed zone assessment.
- A compliance or design check.
- A risk assessment.

Training

Regardless of whether the course was conducted in Queensland, New South Wales or Victoria, the overwhelming majority of participants noted that road safety audit workshop is largely an overview session on 'process', and that auditing is experience / judgement based. Other than the short overview workshop, there is no initial or intensive specialist road safety audit training available. Participants stated that this results in a large proportion of accredited senior auditors with low-to-limited auditing experience, and a small proportion of practicing auditors with rich auditing experience.

Other noteworthy comments include:

- "Having done the training helps staff understand how to respond to audit points".
- "Councils send staff to RSA training not necessarily to be able to do audits, but just to get experience and become more proficient in safety".
- "the (Qld) CARS RSA course was much more interesting than the NSW one, but it still doesn't teach you about auditing".

Accreditation

A recurring theme raised was that the accreditation standard is insufficient for progression to the status of 'senior auditor', and there is a stark lack of tested and verifiable requirement on whether or not the auditor has specialist skills and general experience to be conducting any or all stages of road safety audits.

Victoria

The requirements to become a senior road safety auditor in Victoria are:

- "a copy of a certificate from a recognised road safety audit training course, of at least two days duration;
- a brief breakdown of relevant experience, with a focus on road safety engineering, road design, traffic management or road user behaviour experience;
- at least five years' experience in a relevant road design, road construction or traffic engineering field (this is a minimum and team leaders for audits of more complicated projects should have significantly more experience);
- at least five formal road safety audits undertaken under guidance of a Senior Road Safety Auditor, including at least three at design stages; and
- for Senior Road Safety Auditors to retain their status, they must keep their professional experience current by undertaking at least one audit per year." [2]

NSW

The requirements to become a senior road safety auditor in NSW are similar to Victoria. Besides slightly more onerous requirements for 'number of audits' and 'time in industry', the main differences (for the Level 3 auditor) are:

- must undertake a lead audit training program
- must have a reference from a recognised Level 3 auditor [3]

It is noted that the lead auditor training program is a one-day course and is focussed on leading a team and project management. It does not train or test in technical proficiency[4].

The standard of senior road safety auditor accreditation changed very little since it was agreed on in the 1990s by state road authorities to encourage people to train in this area. [5] [6].

Discussion

A prospective client seeking a road safety audit for the first time has no way of evaluating the level of experience or specialisation of 'Senior Auditors'. The skills, experience and specialisations of individual auditors are at best self-declared. They are not externally or systematically validated.

The current system could be compared to a common vehicle roadworthy test. The roadworthy test gauges a basic set of minimum safety criteria. It does not evaluate mechanical reliability or quality.

It could be argued that none of this matters because quality is assured by clients seeking auditors with reputation. This is likely to be the case with some proportion of audits. However, many 'clients' are not road authorities, but are designers or contractors who have won a project extremely competitively. It is their decision on who to choose to carry out the audit, and it is an obvious commercial interest to have the audit as cheap as possible with minimal problems raised. As such, the quality of a road safety audit can easily become traded off for cost.

As noted by one participant: "If they are just being done for the sake of doing them, and the client has a low understanding of them and they are simply seeking the lowest price, there is very little value in conducting the audit at all".

Thoughts from participants

Participants with particularly deep and long experience with road safety audits expressed:

- "It's the 'elephant in the room' issue, and an embarrassment, and completely undermines the credibility and value of audits and auditors".
- One participant explained that their employer doesn't rely on 'senior' status but have their own internal 'junior-senior' and 'senior-senior' due to the ease of obtaining senior auditor status.
- One participant proposed a portfolio system whereby you submit each audit to the accreditation management system, and it shows your 'total' and 'type' and what (if any) specialist areas it comprised. The quality is still non-validated, but this still presents a more robust reflection of an auditor's skills and experience.

What is an audit and what is it for?

Continual feedback was that there is a lack of understanding in the industry as to what a road safety audit actually is. It is suspected that the use of the word 'audit' in '*road safety audit*' may forever contribute to the perception of a road safety audit as a checklist-based exercise of compliance issues. A road safety audit is in fact a subjective non-compliance based exercise of looking at all of the safety issues together and on their merits, which is very different to this perception.

Feedback on perceptions and understandings:

- “An important tool for the road authority. Also, one taken very seriously due to F.O.I.”
- “Can save costs, lead to better designs and prevent planning mistakes. At the same time a poor quality audit can also trigger the exact opposite.”
- “Used as a backup and ‘sanity check.’”
- “Used as risk sharing measure.”
- “Often it’s a ‘compliance or design check’. If not a directly stated aim, it’s the implication.”
- “A recommendation ‘has to be done.’”
- “The audit is often done due to the regulatory requirement, with little interest in the value-add or skill-set of the audit team.”

Road Authorities (Vicroads)

There was strong repetitive feedback about Vicroads’ approach to road safety audits and process. This feedback came equally from *within* Vicroads. This is summarised below:

- Vicroads are relying very heavily on audits and take them very seriously.
- A common phrase is “let’s see what the auditor says”.
- Reports are increasingly being used to make a decision rather than guide a decision.
- There is a feeling that road safety audits are being used to create a paper trail that removes liability or transfers risk.
- Some Vicroads delivery engineers administering audits make inappropriate requests to removing points e.g. where an issue is outside of the physical scope of project but directly created by the project.
- There is very little administrative flexibility to allow Vicroads designers to question or reject an audit point due to internal policy structures.

The author was advised by Vicroads staff that a contributing factor to the above trends is that the last ten years at Vicroads has seen an acceleration in process-driven roles and a reduction in broad skills sets.

Value

There was a perception by some that audits are not being used as intended; to add value and guide a design from its early stage. As one interviewee asked this rhetoric question: “Is it an ass-covering exercise, or is it actually for uncovering fundamental flaws?”. Other relevant comments on *value*:

- “75% of the value of a road safety audit is from the quality of the auditor/s and the knowledge/understanding of the designer/client. The other 25% comes from how well the audit scope is defined and framed.”
- “The biggest value for RSAs is using the highly qualified auditors to assess relative-risk and comparable-risk at project planning stage. It may not technically be ‘right’ but it’s the best outcome. Most formal audits are of far less value. Auditing a simple temporary lane closure is just sausage factory auditing. Auditors should be used to *form* the concept design, not just audit the designs.”

Audit Recommendations

Participants had wildly varying views on recommendations. At the one extreme, there was a view that there should be detailed recommendations with images/mock-ups, definitive findings, and no uncertainty in language. At the other extreme, recommendations should be brief with ‘open’ language.

Some believed that the cost of a treatment should have absolutely no bearing on audit recommendations. Others were strongly supportive of ‘realistic’ and ‘cost effective’ recommendations commensurate with project size (which is more consistent with the Austroads guidelines) [7]. People with the latter view explained that there’s no point pushing for the relocation of a power pole that’s being brought slightly closer to traffic for $40,000 if the project value is only $100,000 to begin with. Other observations:

- Recommendations can be difficult for a road authority because their processes do not allow them to ‘disagree’ with a finding. They are very sensitive to Freedom of Information requests and perceive a disagreement to a finding as a legal liability.
- Recommendations could ‘distract’ the response. i.e. the client might reject the recommendation it is not feasible, but fail to respond in some other way to the audit point.
- Providing detailed recommendations should only be done if the auditor has a good understanding of the specific topic.

Defining ‘independent’

A road safety audit is an ‘independent’ assessment. However, participants had highly varied opinions on what this means. An astute observation was raised that, although independence can potentially be eroded by ‘internal’ audits, they just as equally have the potential to be eroded if one individual own-practice auditor services the one client year-in year-out. This is due to the relationship that’s formed and the potential financial dependency.

Highly experienced auditors tended to have the view that, as long as the individual auditors are not connected to the project, it shouldn’t matter if it’s technically the same organisation. Or, that audits within the same company can still be independent, as long as a different office is used. Indeed, several people stated that they are ‘harder’ on their own offices than on external clients. Some felt quite strongly that it should be a completely different company / organisation. One interesting observation was that an ‘external’ audit will be used when it “helps the cause”, in situations where a third part might see an ‘internal’ audit as non-credible. A minority view was that a different audit team/company should be engaged to carry out different stages of design audits.

Regardless of the above views, several participants agreed that, if this is tested in court at say a coronial inquest, a judge is unlikely to deem the same company/organisation as ‘independent’.

Influence by client

There was a strong feeling by some that an auditor can be influenced by ‘developer’ clients, and that an audit quality varies markedly and some auditors seem to ‘go easy’ on the client. This is difficult to measure. Some comfort might be able to be taken from the following: Kenn Beer of Safe System Solutions P/L stated that, whilst employed at Vicroads, part of his role in the Road Safety department was to oversee the administration of road safety auditing. As part of that role he was approached on occasion by staff with examples of what they saw as an audit not raising the typical issues that it should, implying that they were merely siding with the client. Kenn stated that, in his opinion, issues raised pertained to differences in professional opinion/judgement, or inadvertent error. He stated that of the audits he reviewed there was no proof of unethical behaviour.

Influenced deemed to be ‘acceptable’ by participants were:

- Changing a risk rating or a recommendation if the auditor is provided with further information or clarification.
- Manipulating the scope of the audit so that a point is not included.
- Omitting all recommendations.

Structure and language

There were two main views expressed which were diametrically opposite.

- A rigid report structure should be followed as per the examples in the Austroads guide.
- The examples in the Austroads guide are old and only rough guides. A flexible report structure should be used, tailored to suit the project at hand.

Miscellaneous issues/insights raised

- Some clients strictly insist on ‘at least two auditors’ must be used for the audit. More experienced auditors quipped that “the skill of the individual/s is far more relevant to quality than the ‘number of auditors’. Five times zero is still zero”.
- “Maybe adjacent councils should audit each other’s work even if it’s not as formal as a road safety audit. There’s lots of expertise in the industry. We should use it. It would add value, and would assist with training and professional development and help us get better at our jobs as an industry”.
- “The Austroads risk rating table is not good. We’d prefer that the auditor just use their judgement with a subjective ‘high/medium/low’ risk rating.”
- “The client looks down on you if you ‘agree’ with auditor because it makes it look like you have designed poorly and even the smallest change costs them money.”
- Some organisations felt threatened by the potential legal liability raised through the audit. This has changed their behaviour by undertaking ‘internal safety reviews’ rather than road safety audits, with the view that this does not “lock them in” as much.
- Views were expressed that night site inspections are not required on a small but significant proportion of audits.

Key issues for action

The following ‘key issues for action’ emanate from the survey work and the auditor’s experiences entrenched within the industry. However, ideally these would be replicated, verified, refined, and adjusted as a result of a larger and more formal national review of road safety audit processes/practices. This would maximise inclusiveness and cover more jurisdictions and further target the overarching question of: “what constitutes a quality road safety audit and how do we get there?”.

Key issues

- Greater auditor accountability for signing off on audits and their claim to be suitably qualified to participate in or lead the audit.
- Mechanism to ensure that audit points are, at an absolute minimum, understood by the people responding to the point.
- A higher standard of accreditation and a nationalised system.
- Modernisation of audit report production methods.
- Transparency and availability of auditor-client discussions and records management.
- Meta data acquisition and storage to steer research, guidelines, practices and knowledge.
- Establishment of a road safety auditor industry organisation.

Key Recommendations

1. Central reporting and management system for:

- Sophisticated software tools for field-work and data capture, report writing, report communications and communication tracking.
- Skill and experience tracking with verification and peer-review module.
- Audit ‘package’ storage (reports, images, communications etc.)
- Generic and site specific road safety audit data gathering

2. A model accreditation system:

- Auditor rating based on knowledge and experience, giving a professional rating and an acknowledgement of specialisations
- Verification and peer-review system
- Testing module

3. National Peak Body of Road Safety Auditors

- Be the peak Australian road safety audit organisation for resources, knowledge and networking.
- Provide guidelines for auditors and clients covering the practical day-to-day questions and concerns that the Austroads guide is not designed to or equipped to cover.
- Peak organisation for third parties to seek guidance, second opinions, peer review, auditing arbitration, and so on, where there are disputes on issues or risk levels in relation to audits.

- Provide a Code of Conduct for auditors

4. Using the Information Hub

Use the system from recommendation 1 to interrogate data to provide feedback on industry practices for constant learning and improvement, and to steer research. A brief example listed below:

- What road / intersection has been 'audited'? When? What type? By who?
- What were the findings?
- How many audits are carried out?
- What type of audits are carried out?
- What are the categories of issues raised?
- What proportion of audit points relate to compliance issues? what proportion relate to first-principles safety issues?
- How many audit points are accepted / rejected?
- What is the experience level of the person responding to the audit?

Acknowledgements and Participants

The contribution from the industry was critical to writing this paper. Apologies are made to people who would have liked to contribute but were not contacted. This is primarily due to this exercise being undertaken by the author as a personal initiative in a limited time span with no funding. The author is grateful for the time and enthusiasm that people spent contributing to this discussion. Some travelled distances to meet with the author. Some went out of their way to host meetings and organise staff from their or other organisations to attend. The collective experience of the participants is approximately 1100 years.

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Older adults and driving reduction: is the gender gap narrowing?

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Abstract

This study investigated driving reduction in a diverse sample of 229 male and female older drivers aged 70 years and above in Queensland, Australia. The study sought to determine whether differences existed between male and female older drivers in regard to driving patterns, and to identify factors that were predictive of driving reduction in female versus male older drivers. Participants provided information on their health, self-reported driving patterns, driving perceptions, alternative transport options, and feedback. Overall, females were more likely to avoid challenging situations but less likely to reduce their driving when compared to males. Self-rated health and driving confidence were significant predictors for driving reduction among females. For males, driving importance was the only significant predictor for driving reduction in this sample. This study indicates the need for longitudinal research on the process of driving reduction and whether the planning process for driving cessation differ between females and males.

Introduction

Older women drivers are over-represented in serious injury and fatality crashes compared to older men due to their increased fragility (Oxley, Charlton, Scully, & Koppel, 2010). The future cohort of older women will rely more on their private cars and may be more reluctant to give up driving compared to current and past generations (Rosenbloom & Herbel, 2009). If women choose to drive when they are no longer safe to do so, they may be putting themselves and others at risk (Rosenbloom & Herbel, 2009). On the other hand, older women have a higher disability rate than men of similar age (Alsnih & Hensher, 2003) and may require more assistance to maintain their mobility needs. With the increasing number of older women living alone (Siren, Hakamies-Blomqvist, & Lindeman, 2004), it is expected that cessation of driving among this age group will have drastic consequences (Siren et al., 2004).

Older women are more likely to stop driving before older men (Kostyniuk & Molnar, 2008). This is partly due to how women view the role and the importance of driving. For women, driving is an essential mean to meet their daily practical needs (e.g. family commitments) while for men it is key to their identity and freedom (Musselwhite & Haddad, 2010b). In addition, older women may lack confidence in their driving as they often have less driving experience when compared to men (Marottoli et al., 1993). As women are starting to resemble men in terms of education and employment, their driving experience and their attitude towards driving may start to resemble that of men (Rosenbloom, 2006). Driving will become an integral part of their identity, and similar to men, it will be the key to their freedom and independence (Rosenbloom & Herbel, 2009).

Self-regulation can be regarded as a mechanism for coping with the declines in driving ability some older drivers may experience (Choi, Adams, & Mezuk, 2012) in an attempt to maintain their driving privilege (Charlton et al., 2006). Driving reduction is one of the most common self-regulatory behaviour adopted by ageing drivers (Molnar et al., 2013; Raitanen, Törmäkangas, Mollenkopf, &

Marcellini, 2003). It is still however unclear if the factors that predict driving reduction among older drivers differ by gender.

This cross-sectional study investigated self-reported driving behaviours and self-reported driving reduction among a sample of older drivers in Queensland, Australia, with the aims of (a) identifying the psychosocial and environmental predictors of the decision to reduce driving and (b) if these predictors differed between males and female.

Methodology

Participants (N=229 after elimination of 18 with key information missing) were recruited through various strategies such as flyers posted and distributed in seniors' clubs, geriatric clinics, and local shopping centres, advertisements in local newspapers and through social media. Eligible participants were current drivers aged 70 years and older. Participants completed the questionnaire online or in a paper-based form with a paid return envelope to the principal researcher. Both questionnaires included an information sheet describing the nature of the study and completing the questionnaire was considered evidence for consent to participate. All participants received the chance to enter a draw to win one of ten $50 shopping vouchers. All procedures were approved by the Human Research Ethics Committee of Queensland University of Technology. Table 1 (which is described in more detail below) provides an overview of the sample.

Materials

Outcome variables

Self-reported driving reduction: rating of overall amount of driving compared to ten years ago on a 4 point scale from "much less" to "more" (grouped into two categories: "much less, a little less" vs "the same, more").

Self-reported driving frequency: annual kilometres driven - "less than 5,000 km/year", "5,001-10,000 km/year", "10,001-20,000 km/year", 20,001-30,000 km/year" and "more than 30,001 km/year" (collapsed into "less than 5,000 km/year", "5,001-10,000 km/year" and "more than 10,001 km/year").

Independent variables

A total of 15 independent variables were included in the regression analysis. Several variables were collapsed into two or three alternatives in order to obtain meaningful categories with respect to the purposes of the study.

Socio-demographic variables: age (years), living condition (alone or with spouse), principal driver (yes or no), self-rated health ("very poor", "poor", "fair", "very good", and "excellent"), driving experience (length of possession of an open driving license); feedback about driving from doctor or family members (discussion about driving in the past year); life goal decisions (moving to an aged-care facility, moving closer to public transport, or moving closer to common destinations).

Psychosocial variables: importance of driving ("extremely important", "very important", "moderately important", "somewhat important", "not that important"); perceived driving ability scale (PDA), a previously validated 15-item scale (MacDonald, Myers, & Blanchard, 2008) measuring participants' current perceived driving abilities (''poor'', ''fair'', ''good'', ''very good"); driving stress scale measuring experienced stress in a number of driving situations (four points from "heavy stress" to "no stress") with a mean "Driving Stress" score (Hakamies-Blomqvist, 1994a); driving confidence for 10 driving conditions (10 points from "not at all confident" to "completely confident" with a total mean score (Marottoli & Richardson, 1998); a driving relinquishment scale developed to assess participants' views about the importance of driving and barriers toward giving up driving using agreement with eight statements and taking a mean scale score. Psychometric properties of all scales used in this study are shown in Table 2, together with means and standard deviations.

Analysis

Data were analysed in SPSS version 20.0 (IBM Corporation, Armonk, NY). Differences between those who reduced and those who did not reduce driving on each of the 15 independent variables were examined using Chi-square analysis and t-test statistics. Then differences between amounts of driving measured by the annual km driven on each of the 15 independent variables were examined. A preliminary regression analysis confirmed that gender was a significant predictor for self-reported driving reduction. After this, the sample was divided into males and females, and further analyses were conducted. Binary logistic regression modelling was used to determine the characteristics of those who reduced their driving compared to those who did not for both males and females. A hierarchical regression model was developed, where the effect of age and driving experience was controlled for. The analysis therefore focused on the effect of modifiable psychosocial and environmental factors. Intercorrelations between predictor variables showed no excessive multicollinearity. Relevant independent variables were included in the analysis with a p-value cut-off point of 0.25. Stepwise logistic regression was conducted and variables were retained in the model at a $p<0.05$.

Results

Sample characteristics and significant gender differences

The sample ranged in age from 70 to 94 years (M= 75.6, SD ± 5.2), and included 92 females (40.2 %) and 137 males (59.8%) (Table 1). Around 60.7% of the participants reported living with a spouse or partner and significantly more women were living alone compared to men (51.1% vs. 21.9%, ($\chi2$ (2) = 24.487, $p <0.001$)). Men had significantly more driving experience compared to women (t (227) =-4.08243, $p<0.001$)

The number of annual kilometres driven was significantly different by gender ($\chi2$ (2) = 7.135, $p <0.05$). For men, participants who reported driving less than 5,000 km/year also reported greater reliance on their family compared to those who drove 5,000-10,000km/year and more than 10,001 km/year (70.8% vs. 45.6% vs. 33.9% ($\chi2$ (2) = 9.241, $p <0.01$). In addition, those who reported driving more than 10,001 km/year reported driving to be extremely important compared to the other two groups (50% vs. 35.1% vs. 20.8% ($\chi2$ (4) = 13.589, $p <0.009$). Participants who reported using in-vehicle technology were more likely to report driving more than 10,001 km/year than those who did not use it (54.5% vs. 16.3%, ($\chi2$ (2) = 22.847, $p <0.001$). Doctor's feedback about driving was also significantly associated with driving less kilometres per year ($\chi2$ (2) = 7.386, $p <0.025$). Annual kilometres driven groups were also significantly associated with age (Welch's F (2, 56.296) = 9.010, $p <0.001$), PDA scale scores (F (2, 134) = 4.522, $p < 0.01$), stress scale scores (F (2, 134) = 4.915, $p < 0.009$), and confidence scale scores (Welch's F (2, 57.686) = 6.448, $p <0.01$). For women, annual kilometres driven groups were significantly associated with stress scale scores (F (2, 89) = 4.862, $p < 0.01$), driving relinquishment scale score (F (2, 89) = 4.135, $p < 0.01$), and confidence scale scores (F (2, 89) = 4.150, $p <0.01$).

The majority of participants (69.9%) indicated that they have reduced their overall driving compared to ten years ago. However, males were significantly more likely to reduce their driving compared to females ($\chi2$ (1) = 10.980, $p <0.05$). The most avoided driving situations were driving at peak hour (35.5%), and night driving (31.6%), however there were no significant differences between males and females for these situations. Females reported greater avoidance compared to males of driving long distance (43.5% vs. 21.3%), in the rain (31.5% vs. 17.6%), on freeways (24.2% vs. 11.9%), as well as parallel parking (21.7% vs. 9.6%) and lane changing (12% vs. 3.7%). Females also scored higher on the avoidance scale (which indicates greater avoidance behaviour) (t (168.510) = 3.419, $p <0.001$).

There were no significant differences between males and females in terms of rating on the PDA scale and the driving relinquishment scale. However, females were significantly more likely to rate driving as extremely important compared to males ($\chi2$ (2) = 6.561, $p <0.038$). In addition, females reported higher scores on the stress scale (0.31, t (227) = -4.013, $p <0.001$) and lower scores on the confidence scale (0.67, t (227) = -2.511, $p <0.05$).

Driving reduction

An initial analysis examined the association between driving reduction among the whole sample and the independent variables. Driving reduction was significantly associated with gender ($\chi2$ (1) = 10.980, $p <0.001$) with more males than females reducing their driving (78.1% vs. 57.6%). Driving reduction was also significantly associated with increasing age (t (227) = -2.543, $p <0.012$) and with increased driving experience (t (227) = -2.772, $p <0.006$). Around 82.4% of participants living in retirement homes reduced their driving compared to 66.3% of those living in their private home ($\chi2$ (1) = 4.857, $p <0.028$). Participants who rated their health to be very good or fair reported greater driving reduction compared to those who rated their health to be excellent (80.8% vs. 72.1% vs. 48.8% ($\chi2$ (2) = 11.906, $p <0.003$)). Participants who rated driving to be extremely important reported less reduction of their driving ($\chi2$ (2) = 23.402, $p <0.001$). Participants who had discussed their driving with their doctor reported more reduction compared to those who had not (79.6% vs. 62.6% ($\chi2$ (1) = 7.693, $p <0.006$)) and the same with family's feedback (80.4% vs. 62.1% ($\chi2$ (1) = 8.886, $p <0.003$). Lower ratings on the PDA scale were also significantly associated with driving reduction (t (227) = 2.339, $p <0.05$) as well for the diving confidence scale (t (180.961) = 2.851, $p <0.005$).

Separate analyses were then conducted to examine driving reduction for males and females. For men, driving reduction was significantly associated with self-rated quality of driving ($\chi2$ (2) = 7.545, $p <0.023$), driving importance ($\chi2$ (2) = 16.028, $p <0.001$), and doctor's feedback ($\chi2$ (1) = 4.688, $p <0.030$). For women, driving reduction was significantly associated with self-rated health ($\chi2$ (2) = 9.310, $p <0.01$), driving importance ($\chi2$ (2) = 6.889, $p <0.032$), moving to a place with better public transport options ($\chi2$ (1) = 6.366, $p <0.012$), family's feedback ($\chi2$ (1) = 5.598, $p <0.018$), PDA scale (t (90) = 2.032, $p <0.045$), and confidence scale (t (89.977) = 2.924, $p <0.004$).

Table 1. Sample characteristics (n=229)

	Overall sample (n=229)	**Female (n=92)**	**Male (n=137)**
Mean age in years (SD)	75.6 (5.2)	75.4 (5)	75.7 (5)

Principal driver			
Yes	159 (69.4%)	65 (70.7%)	94 (68.6%)
No	70 (30.6%)	27 (29.3%)	43 (31.4%)
Education			
Primary/Secondary school	109 (47.6%)	***54 (58.7%)***	***55 (40.1%)***
Certificate	56 (24.5%)	***18 (19.6%)***	***38 (27.7%)***
University degree	64 (27.9%)	***20 (21.7%)***	***44 (32.1%)***
Dwelling			
A private home	178 (77.7%)	76 (82.6%)	102 (74.5%)
A retirement home or seniors' complex	51 (22.3%)	16 (17.4%)	35 (25.5%)
Living condition			
Alone	77 (33.6%)	***47 (51.1%)***	***30 (21.9%)***
With spouse or partner	139 (60.7%)	***38 (41.3%)***	***101 (73.7%)***
Other	13 (5.7%)	***7 (7.6%)***	***6 (4.4%)***
Employment			
Yes	68 (29.7%)	30 (32.6%)	38 (27.7%)
No	161 (70.3%)	62 (67.4%)	99 (72.3%)
Driving experience, years open driving license (mean and standard deviation)	55.2 (0.4)	***52.8 (0.7)***	***57 (0.5)***
Annual km driven			
Less than 5,000 km/year	53 (23.1%)	***29 (31.5%)***	***24 (17.5%)***
5,000-10,000 km/year	94 (41%)	***37 (40.2%)***	***57 (41.6%)***
More than 10,000 km/year	82 (35.8%)	***26 (28.3%)***	***56 (40.9%)***
Public transport use			
Frequently/Sometimes	81 (35.4%)	32 (34.8%)	49 (35.8%)
Never/Rarely	146 (63.8%)	59 (64.1%)	87 (63.5%)
Family ride			
Frequently/Sometimes	115 (50.2%)	53 (57.6%)	62 (45.3%)
Never/Rarely	114 (49.8%)	39 (42.4%)	75 (54.7%)
Taxi use			
Frequently/Sometimes	19 (8.3%)	11 (12%)	8 (5.8%)
Never/Rarely	210 (91.7%)	81 (88%)	129 (94.2%)
Moving closer to common destinations			
Yes	56 (24.5%)	23 (25%)	33 (24.1%)
No	173 (75.5%)	69 (75%)	104 (75.9%)
Moving to an aged-care facility			
Yes	33 (14.4%)	11 (12%)	22 (16.1%)
No	196 (85.6%)	81 (88%)	115 (83.9%)
Moving to a place with better public transport options			
Yes	49 (21.4%)	***27 (29.3%)***	***22 (16.1%)***
	180 (78.6%)	***65 (70.7%)***	***115 (83.9%)***

No			
In-vehicle technology use (e.g. navigation system, cruise control, blind spot detection)			
Yes	125 (54.6%)	***37 (40.2%)***	***88 (64.2%)***
No	104 (45.4%)	***55 (59.8%)***	***49 (35.8%)***
Driving reduction			
Reduced	160 (69.9%)	***53 (57.6%)***	***107 (78.1%)***
Not reduced	69 (30.1%)	***39 (42.4%)***	***30 (21.9%)***
Self-rated health			
Excellent	41 (17.9%)	23 (25%)	18 (13.1%)
Very good	136 (59.4%)	53 (57.6%)	83 (60.6%)
Fair	52 (22.7%)	16 (17.4%)	36 (26.3%)
Driving importance			
Extremely important	101 (44.1%)	***48 (52.5%)***	***53 (38.7%)***
Very important	100 (43.7%)	***38 (41.3%)***	***62 (45.3%)***
Moderately important/Somewhat important	28 (12.2%)	***6 (6.5%)***	***22 (16.1%)***
Self-rated quality of driving	54 (23.6%)	17 (18.5%)	37 (27%)
Excellent	142 (62%)	62 (67.4%)	80 (58.4%)
Good	33 (14.4%)	13 (14.1%)	20 (14.6%)
Average			

Notes: Italic and bold font indicate significant gender differences measured by Chi-square test and independent-sample t-test, $p<0.05$

Table 2. Descriptions of the psychometric properties of scales

Scale	Number of items	Mean	SD	Scale actual range	Scale sample range	Cronbach's alpha
PDA scale	15	2.3	0.5	0-3 (3 higher ratings)	0-3	0.93
Driving stress scale	16	1.98	0.6	0-3 (3 less stress)	0-3	0.94
Driving relinquishment scale	8	1.3	0.5	0-3 (3 indicates more positive attitude)	0-2.6	0.8
Driving confidence scale	10	7.77	2.0	1-10 (10 indicates more confidence)	1-10	0.96

Predictors of driving reduction

After adjusting for the effect of age and driving experience, self-rated driving importance was the only significant predictor of driving reduction among males (Table 3). For females, self-rated health and driving confidence were the only significant predictors of driving reduction (Table 4).

Table 3. Logistic regression analysis and the best predictor variables for driving reduction among males (n=137)

	B	SE	Odds ratio	*P* value	95% CI of odds ratio
Driving importance (reference extremely important)					
Very important/ Moderately important	1.648	0.460	5.2	0.001	2.1-2.8

$\chi 2$= 18.391, *p<0.001*, Nagelkerke R2=0.193

Table 4. Logistic regression analysis and the best predictor variables for driving reduction among females (n=92)

	B	SE	Odds ratio	*P* value	95% CI of odds ratio
Self-rated health (reference fair)					
Excellent	-1.502	0.752	0.2	0.04	0.05-0.97
Confidence scale	-0.329	0.133	0.7	0.01	0.55-0.93

$\chi 2$= 18.954, *p<0.001*, Nagelkerke R2=0.25

Discussion

The main aim of this study was to examine the predictors of driving reduction among older drivers and if they differ by gender. Around 70% of participants reported that they have reduced their driving compared to ten years ago. Previous studies demonstrate that older women are more likely to self-regulate their driving when compared to older men (Kostyniuk & Molnar, 2008). In our study reduction of driving was significantly more prevalent among males than females (78.1% vs. 57.6%). However, females reported significantly greater avoidance than males in a number of challenging driving situations which is consistent with other studies (driving in the rain (Rosenbloom & Herbel, 2009) and merging (Charlton et al., 2006). Regardless of gender, it appears that older drivers avoid a small number of driving situations. Men reported driving significantly more annual kilometres compared to women. For women, driving less annual kilometres was significantly associated with scores on the driving stress scale, driving confidence scale, and driving relinquishment scale.

Overall, females reported significantly higher driving stress and less driving confidence compared to males. Older women often report lack of confidence in their driving abilities and report that driving is stressful (Kostyniuk & Molnar, 2008). However, there were no significant differences in self-rated quality of driving between males and females with the majority of participants reporting higher scores on the PDA scale. Previous studies have reported that older drivers tend to overrate their driving abilities and performance (Ackerman et al., 2011).

The results of the binary logistic regression showed that predictors of driving reduction differ between males and females. For men, the importance of driving was the only significant predictor in the final model. Men, regardless of their age, view driving as key to their independence and freedom (Rosenbloom & Herbel, 2009). For women, self-rated health was a significant predictor for driving reduction. Several health and physical functioning measures have been longitudinally associated with later cessation of driving (Anstey, Windsor, Luszcz, & Andrews, 2006). However, older drivers' perceptions of their health conditions and how they impact their driving are far more important factors than their objective health condition (Anstey, Wood, Lord, & Walker, 2005), and there is evidence suggesting that older women give up driving earlier than they should and impose unnecessary restrictions on their mobility (Siren et al., 2004). The other significant predictor for driving reduction among older women was driving confidence. Numerous studies points out to the significant association between self-reported driving confidence/comfort and driving behaviour (Blanchard & Myers, 2010). This also could be the reason why female are more likely to self-regulate or stop driving than men (probably prematurely) (Siren & Meng, 2013) as they report loss of confidence as the reason they give up driving more than males do (McNamara, Chen, George, Walker, & Ratcliffe, 2013).

Previous literature has suggested that in the future, older women may rely more on their private cars for their mobility and will be more reluctant to give up driving compared to current and past generations of older women (Rosenbloom & Herbel, 2009). The findings in this study indicate that the gender gap may be narrowing and that as more women are living alone, driving is becoming extremely important to maintain their independence.

This study had some limitations. The recruitment strategy may have attracted relatively more active and healthier drivers; cognitive functioning was not assessed; very few participants reported that they were involved in a crash recently which made it difficult to explore this variable; and the study employed a cross-sectional design. Further, the study relied on self-report measures of driving behaviour. Recent findings suggest that self-report measures of driving behaviours don't match objective measures of real-world driving. For instance, older drivers cannot accurately estimate their driving distances (Huebner, Porter, & Marshall, 2006) and they tend to drive more frequently in challenging situations than what they actually report (Blanchard & Myers, 2010).

The results from this study are consistent with previous findings that show self-rated driving confidence is a significant predictor of driving regulation among older females. Interestingly, females were less likely than males to reduce their driving. This could mean that the gender gap may be narrowing. Further research is needed to investigate driving reduction among female drivers. In addition, in-depth qualitative research is needed to capture the reasons why older women reduce and/or stop driving and how this impacts their mobility needs.

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Developing the ASEAN Regional Road Safety Strategy

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Abstract

In 2011, more than 75,000 people died in road crashes in the ten member countries of the Association of South East Asian Nations (ASEAN) and many times this number sustained long term injuries. Improving road safety outcomes in ASEAN is not only important for the welfare and economic benefit of these countries, but given that a significant proportion of the world's population lives in ASEAN, it will strongly influence whether the aims of the United Nations Decade of Action for Road Safety and the Sustainable Development Goals are reached. For this reason, the Asian Development Bank, funded by the Japan Fund for Poverty Reduction, has funded a package of action to improve road safety in ASEAN, including the development of a regional road safety strategy. The diversity of the member nations of ASEAN poses significant challenges for the development of the strategy. For example, the road fatality rates per 100,000 population in Malaysia and Thailand are about 5 times greater than in Singapore. In addition, the importance of particular road safety issues varies across the ASEAN countries and for countries which are undergoing rapid motorization, the order of importance may change over the life of the strategy. The development of the ASEAN Regional Road Safety Strategy has adopted the five pillars of road safety of the UN Decade of Action but focused on those aspects which are most relevant at the regional level and where a regional approach will support and facilitate actions taken by individual countries.

Introduction

Road trauma has incredible impact on the health and economic growth of all nations. The World Health Organization (WHO, 2013) estimates that in 2010, 1.24 million people died worldwide from road trauma. Another study has calculated that on a daily basis at least 140,000 people are injured on the world's roads, and 15,000 of these are disabled for life (Sharma, 2008, Al Turki, 2014). Indeed, the deaths attributable to road trauma are estimated to reach 2.4 million fatalities per year by 2030 (WHO, 2013), and road traffic accidents will be the third leading cause of disability-adjusted life years lost worldwide 2020 (Dickinson et al., 2000). The United Nations has recognised the importance of dealing with this problem by announcing 2011-2020 as the Decade of Action for Road Safety. In 2011, it was estimated that more than 75,000 people died in road crashes in the ten member countries of the Association of South East Asian Nations (ASEAN: Brunei, Indonesia, Malaysia, the Philippines, Singapore, Thailand, Viet Nam, Laos PDR, Myanmar, and Cambodia) and many more sustained long term injuries (WHO, 2013). Improving road safety outcomes in ASEAN is not only important for the welfare and economic benefit of the populations of these countries, but given the proportion of the world's population that lives in ASEAN, it will strongly influence whether the aims of the United Nations Decade of Action for Road Safety and the Sustainable Development Goals are reached. For this reason, the Asian Development Bank, funded by the Japan Fund for Poverty Reduction, has funded a package of actions to improve road safety in ASEAN, including the development of a regional road safety strategy. More details of the package of actions are provided in Klein & Haworth (2015) and Sann, Haworth & King (2015).

Each one of the ASEAN countries has reached different levels of maturity in its response to road trauma. The UNDoA has proposed 5 pillars of road safety which provide a useful framework for road safety strategies at the global, regional and national levels: road safety management, safer road and mobility, safer vehicles, safer road users and post-crash response. There has also been a realisation that, within this overall framework, there are particular actions that are best suited to implementation at the global, regional and national levels. It is proposed that the key Strategic Directions for the ASEAN Regional Road Safety Strategy should focus on those aspects which are most relevant at the regional level and where a regional approach will support and facilitate actions taken by individual countries.

Road safety in the ASEAN context

Road trauma is particularly high in low- and middle-income countries, accounting for 91% of the total road fatalities occurring in road crashes (Ameratunga et al., 2006). To date, high-income regions such as Europe and Australia experience approximately 8.7 deaths per 100,000 inhabitants annually, whilst middle-income regions such as Latin America have a higher rate of 20.1 (WHO, 2013). Furthermore, in 2020, road traffic accidents will be the second leading cause of disability-adjusted life years lost in developing countries (Dickinson et al., 2000). The economic and geographic diversity among the ASEAN nations is evident also in road safety outcomes. The road fatality rate per 100,000 population in Malaysia and Thailand is about 5 times greater than in Singapore. The Singaporean road fatality rate in (3.8) is similar to that of the world's best performing nations (Netherlands (3.9) and the United Kingdom (3.1)). The Global Status Report on Road Safety (WHO, 2013) has identified that road trauma is generally higher in middle income countries and still increasing – this is also true in ASEAN. Low income countries (such as Myanmar and Cambodia) generally have lower rates of motorization and so lower fatality rates expressed in terms of population (although the per vehicle rates can be extreme). Unless strong action is taken, economic development in these countries will be accompanied by increasing deaths and injuries on their roads.

The rapid pace of change in some ASEAN countries means that the Regional Road Safety Strategy needs to focus on future issues, as well as the current situation. For some countries increasing motorization may mean that the challenge is to reduce the likely future increase in road trauma, rather than attempting to achieve absolute reductions.

The importance of particular road safety issues varies across the ASEAN countries. The best approach to dealing with this challenge may be to have a set of priority issues in the regional road safety strategy (e.g. non-use of helmets, then drink driving etc.) and acknowledge that the order of importance of these issues will vary among countries. It is possible that for countries which are undergoing rapid motorization, the order of importance may change over the life of the strategy.

Income levels vary markedly among ASEAN countries. Some higher-cost initiatives may be relevant for only a subset of ASEAN countries at the moment and the focus for the remaining countries may need to be on lower-cost solutions. For some initiatives, it may be possible to develop lower-cost alternatives (as has occurred for motorcycle helmets). In addition, disparate income levels exist within countries. It is also important to consider whether some road safety initiatives may lead to loss of income or access to resources by the poor and disadvantaged. For example, banning or restricting the use of unsafe means of transportation which are mainly used by the poor may hamper their access to employment or education. There may be a need for a poverty impact analysis for new road safety programs.

Method

The first step in the development of the ASEAN Regional Road Safety Strategy involved a review of the previous regional strategy and supporting documentation, and strategies and other relevant documents from individual countries. The review identified the strong disparities in levels of economic development and motorization across the region, accompanied by a lack of consistent data collection across and within many member countries. This led to a decision that the strategy should focus on bringing about improvement relative to baseline in each country, rather than setting the same target for each country. The review outcomes also suggested that a semi-qualitative approach towards describing current practices and monitoring improvement would allow measurement across all countries, even those which currently have poor data systems. Therefore, a star rating system for behavioural factors (to parallel star ratings for vehicles and roads) was proposed by the first author and refined by feedback from national representatives at the ASEAN Train the Trainer Workshop in Manila in June 2014. Further input on safety issues in each of the ASEAN nations was also collected as part of a two-day training workshop on Urban Road Safety in Manila in September 2014.

Role and structure of the regional road safety strategy

ASEAN is a unique sub-region, with some countries belonging to other organisations such as the Asia Pacific Economic Forum (APEC), and UNESCAP. In terms of the ASEAN structure, road safety is particularly relevant to Transport Ministers, Senior Officers, the Land Transport Working Group and Multi-sector Road Safety Special Working Group (MSRSSWG). The MSRSSWG is charged with the responsibility to mobilise and deliver the RRSS through ASEAN.

The previous ASEAN regional road safety strategy (RRSS) and action plan entitled “Arrive Alive: ASEAN commits to cutting road deaths” covered the period 2005-2010. Since then the road safety and motorization contexts in many of the ASEAN countries have changed and new approaches to improving road safety have been introduced, spurred on by the announcement of the UN Decade of Action for Road Safety. The UNDoA has proposed 5 pillars of road safety which provide a useful framework for road safety strategies at the global, regional and national levels: road safety management, safer road and mobility, safer vehicles, safer road users and post-crash response. There has also been a realisation that, within this overall framework, there are particular actions that are best suited to implementation at the global, regional and national levels.

Given the disparities in current road safety performance and in the availability of resources among the ASEAN members, and the specific responsibilities of the MSRSSWG, it was decided that the key Strategic Directions for the ASEAN Regional Road Safety Strategy should focus on those aspects which are most relevant at the regional level and where a regional approach can be more useful than an individual country approach. These aspects have been identified as:

1. Harmonisation of standards, road rules and legislation
2. Capacity building
3. Knowledge development through research and evaluation
4. Monitoring and reporting progress

These aspects were chosen because they are relevant to all of the ASEAN members (while more specific actions might be relevant to, or feasible for, only some members), they foster collaboration and learning among members, and they can be well-supported by external agencies where needed. The high-level nature of the four aspects allows the regional strategy to function as a strategic framework within which each member nation is able to develop approaches that are appropriate to their culture and the nature of their transport system, rather than proposing a single “one size fits all” approach.

It is important to note that the RRSS is being developed as part of a package of actions to improve road safety in ASEAN, rather than as a stand-alone document. This was a learning from earlier regional strategies, the success of which was considered to have been hampered by the lack of resourcing for building national capacity. Thus the RRSS is being developed in conjunction with train-the-trainer programs for individuals identified as national focal points and the appointment of ADD-funded national consultants to work with government and other organisations to facilitate implementation of road safety measures.

In the draft strategy, these aspects are presented according to the five pillars proposed to guide national road safety plans and activities during the Decade of Action for Road Safety. These pillars are not truly separate and interactions between them can bring about significant benefits. For example, most engineering measures need education to maximise correct use and therefore benefits. Therefore there is a need to work together to integrate the activities undertaken in the different pillars. For each pillar, an overall goal, general considerations, and specific approaches are proposed in the draft strategy.

A summary of the road safety context and issues for each of the ASEAN nations was prepared and included as part of the draft strategy document. Most of the information was derived from the World Health Organization Global Status Report on Road Safety 2013 (WHO, 2013). For each country, the road safety challenges were summarised at the beginning of the section. A description of the geography, demographics, road fatality patterns and institutional capacity for road safety in that country was then provided. In order to compare road safety performance across countries and across pillars, a Road Safety Maturity Index was developed and incorporated into the draft strategy (see Oviedo-Trespalacios & Haworth, 2015 for a description of the Index).

Conclusions

The development of the draft ASEAN regional road safety strategy posed some unique challenges in terms of identifying the optimal approach for a region characterised by diversity in both road safety issues and levels of economic development. The lack of consistent measures of road safety activity and performance led to the need to create new semi-qualitative measures that would not require extensive resources to collect and monitor. Consultation on the draft ASEAN regional road safety strategy is now underway. The section on road safety context and issues in each country will be enhanced by input from national road safety advisors. The revised document will then be considered by ASEAN officials in late 2015 and further development will follow.

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Speeds and Pedestrians - what's the right mix?

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Abstract

Pedestrians are highly vulnerable in traffic with the young and the aged especially at risk. Impact speed, the stature and fitness of the pedestrian, and the frontal design of the striking vehicle are all influential in determining the severity of outcome of any collision involving a pedestrian. An area of special focus among researchers has been the relationship between impact speed with a pedestrian and the probability of death or serious injury resulting. More recent analyses have suggested that impact speeds as high as 50 km/h coincide with an approximate 10% risk of death to the pedestrian and also mark the commencement of a rapidly rising risk of death for increasing impact speeds above 50 km/h. This result could be construed to mean that travel speeds of 50 km/h are likely to produce acceptable outcomes under a Safe System vision. This paper seeks to briefly review the current state of knowledge regarding travel and impact speeds, and to provide evidence-based support for translating Safe System philosophy and principles into real-world practice.

Introduction

Crashes involving pedestrians in 2013 constituted 13% of all road deaths in Australia and 15% in Victoria (Hoareau, Logan, Oxley and Corben (2014). Pedestrians are highly vulnerable in traffic with the young and the aged especially at risk. Over several decades, significant strides have been taken in improving protection for vehicle occupants in the event of a crash. The cars of today offer over 25% better protection than those that first came off the assembly line in the beginning of the nineties (Newstead and Scully, 2009). Fleet replacement over that time has meant that safety innovations such as side curtain airbags, improved cabin integrity and energy-absorbing componentry are increasingly taking effect in improving the outcome for vehicle occupants when a crash does occur.

Unfortunately, over this same period vehicle technology to improve protection for vulnerable road users such as pedestrians has shown much slower progress. It is true that ANCAP provides a very valuable rating of a vehicle's ability to protect a pedestrian upon impact. A vehicle's frontal design and energy absorbing properties are key determinants of the pedestrian safety rating. Notwithstanding, very few vehicles entering the market over past decades have displayed good to high levels of pedestrian protection. As a consequence, vehicle design factors historically have done little in practical terms to support improved outcomes for crash-involved pedestrians. Encouragingly, over the past decade there have been signs of improvement with Keall, D'Elia, Newstead and Watson (2014) estimating that there were savings across Australia of around 340 fatal and serious injuries to pedestrians relating to average improvements in vehicle characteristics over the period 2003 to 2011.

The importance of speed to pedestrian safety cannot be overstated. One of the most compelling, macro-level illustrations of this fact comes from a simple examination of long-term trends in pedestrian fatalities in Victoria over recent decades.

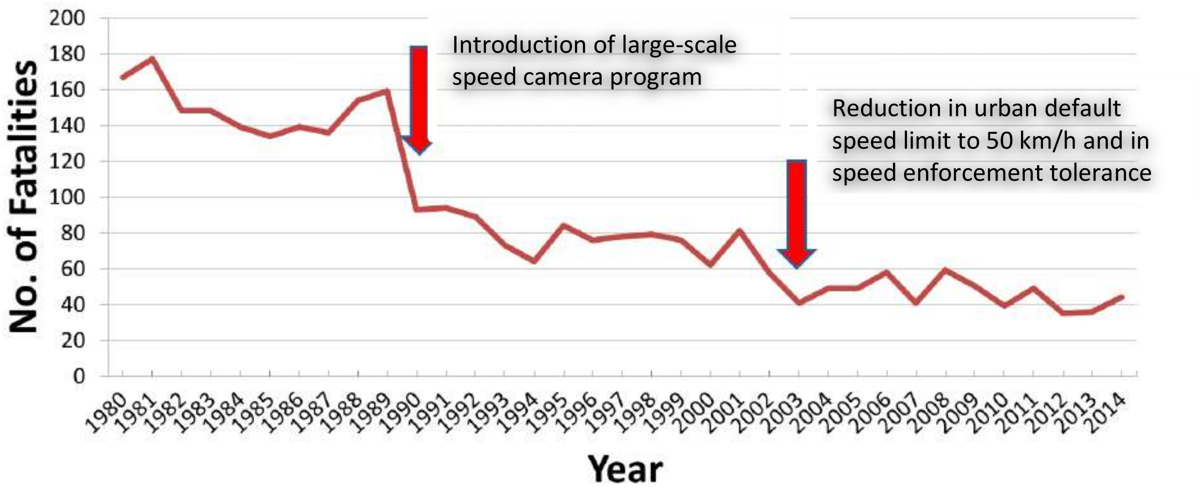

Figure 1: Pedestrian Fatalities on Victorian Roads (1980-2014)

Figure 1 shows the annual number of pedestrian fatalities occurring in Victoria between 1980 and 2014, inclusive. On two occasions over the 35-year period, distinct drops in fatalities can be clearly seen. Neither drop has rebounded to previous levels, as often happens when an observed reduction is likely due to chance rather than to a real effect. Over the last 25 years, the number of pedestrian deaths in Victoria has decreased by some 75 percent, from an average of around 150 deaths per annum in the late 1980s (159 in 1989) to between 35 and 50 deaths per annum since 2010, averaging around 40 fatalities each year for 2010-2014. The two large step-reductions occurred in 1990 and 2002-2003 following the introduction of two major speed initiatives in Victoria. They involved the introduction of 54 automated speed cameras with strong supporting public education in 1989/1990 and, in 2001, a lower urban default speed limit followed soon after in 2002 by a reduction in the tolerance level of compliance with speed limits (along with a range of other improvements in speed enforcement). Since 2003, however, reductions in pedestrian deaths have plateaued.

Impact speed is a key determinant of injury severity. Energy transferred to the human body, in excess of its biomechanical tolerance, will result in potentially life-disabling injury or even death. As a result, an area of special focus for researchers has been the relationship between impact speed with a pedestrian and the probability of death or serious injury occurring. This paper seeks to briefly review the current state of knowledge regarding travel and impact speeds, and to provide evidence-based support for translating Safe System principles into real-world practice.

Research on the Relationship between Fatal or Serious Injury Risk and Impact Speed

Estimating the risk of death or serious injury for a range of impact speeds is a complex exercise. Determining factors include the age and level of functionality of the pedestrian, error associated with the estimate of impact speed itself, varying vehicle frontal profiles and rigidity, orientation of the pedestrian to the striking vehicle as well as biases inherent in sampling cases only at the more severe end of the injury severity spectrum. The following discussion provides a brief overview of progress in the field based on reference to a select number of relevant studies.

Wramborg (2005) gave prominence to the relationship between impact speed and the risk of a pedestrian being killed in the context of developing a safe traffic system in Sweden in his paper to the Road Safety in Four Continents Conference in Warsaw (refer to Figure 2 below).

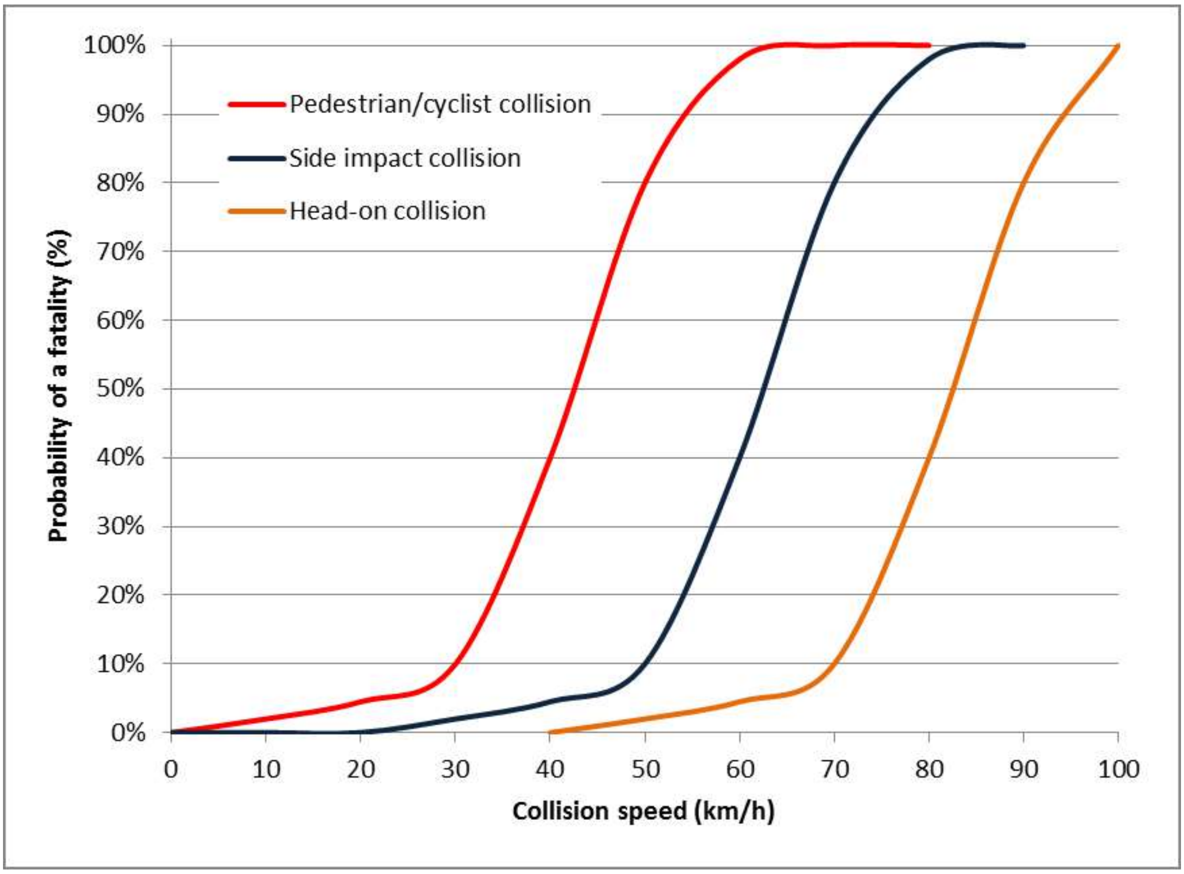

Figure 2: Risk of Pedestrian Death by Impact Speed (after Wramborg)

The risk curves presented above are indicative only but, importantly, point to a general shape in the risk curve such that as impact speeds increase in excess of a threshold value (in the case of a pedestrian, approximately 30 km/h), the risk of death to a pedestrian begins to rise very rapidly.

Rosen, Stigson and Sander (2011) conducted a literature review of key studies that sought to relate fatality risk to the impact speed of a car. Eleven studies in total, conducted between 1980 and 2010, were reviewed. The authors noted that the risk estimates for a given impact speed varied considerably with most studies drawing conclusions from samples of crashes that were biased towards the more severe end of the spectrum. This type of bias is likely to result in inflated estimates of threshold impact speeds. Two studies though, Davis (2001) and Rosen and Sander (2009) made adjustments to the sample to reflect better the profile of crashes across all severities with the result that threshold impact speeds at which there was an estimated 10% risk of a pedestrian fatality increased markedly. In the 2009 study, for example, that examined only car and car derivatives in collisions with pedestrians aged over 15 years, the fatality risk was estimated at 8% at 50 km/h, well in excess of the indicative threshold speed of 30 km/h proposed by Wramborg in his 2005 paper.

Tefft (2011) estimated the risk of death or severe injury for pedestrians aged 15 years and over struck by a car or light truck in the United States using data for the years 1994 to 1998. Weightings were applied to adjust for oversampling of the more severe crash types while use of logistic regression made allowances for variations in pedestrian and vehicle characteristics. The risks so estimated were then re-scaled to represent average risks of death or serious injury to a pedestrian if struck by a car or light truck in the United States in the years 2007 to 2009. Figures 3 and 4 below show the estimated average risks for pedestrian death and serious injury respectively together with 95% confidence intervals. Serious injury was defined as an Abbreviated Injury Scale (AIS) score of 4 or more that equates to a very severe trauma outcome and can include death.

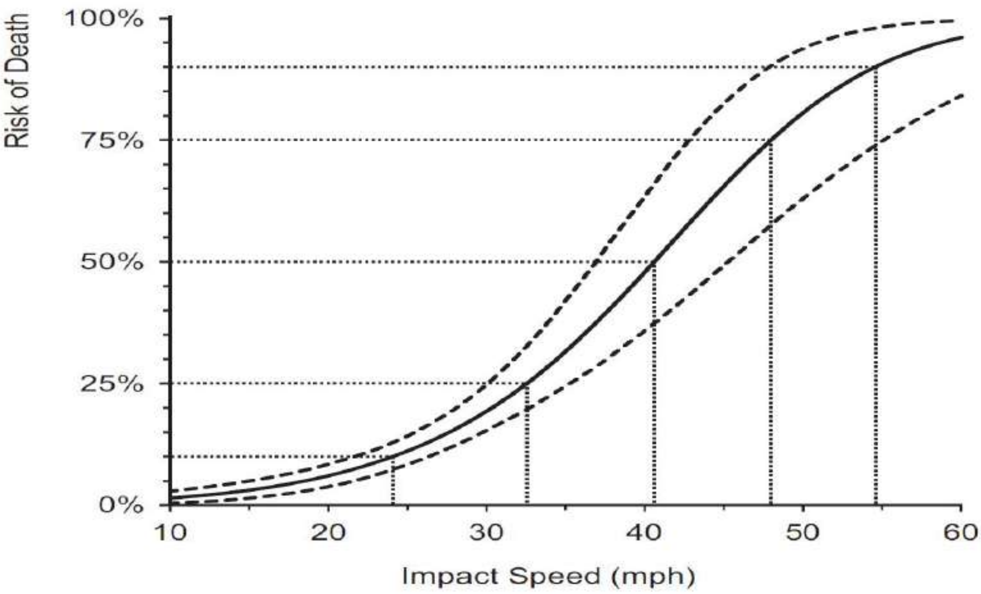

Figure 3: Average Risk of Pedestrian (15+ yrs) Death by Impact Speed (Tefft, 2011)

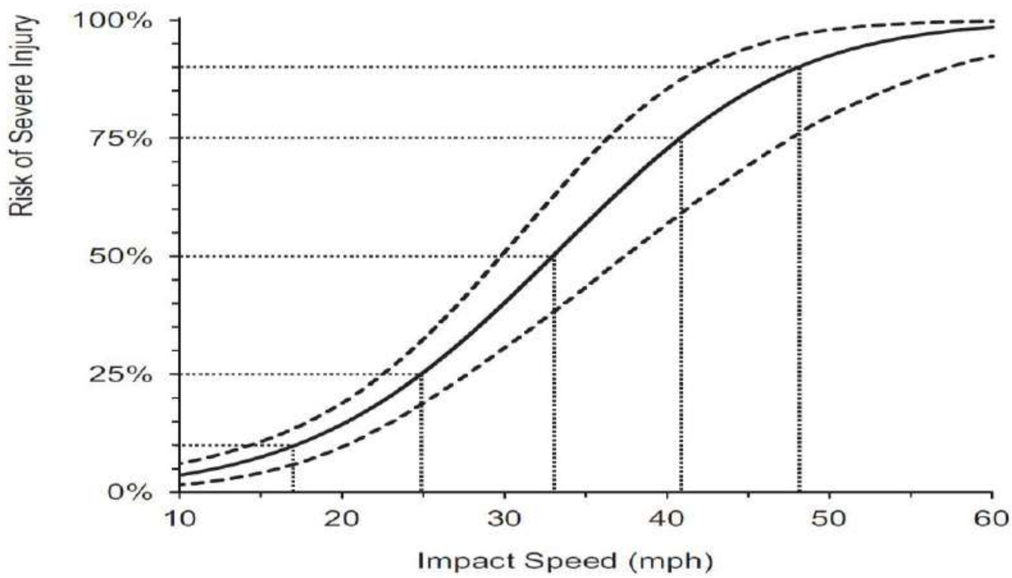

Figure 4: Average Risk of Pedestrian (15+ yrs) Severe Injury by Impact Speed (Tefft, 2011)

While the above results apply first and foremost to the American setting, they nevertheless are instructive for two very good reasons. Firstly, the confidence limits highlight the uncertainty of the estimation procedure notwithstanding every effort to manage confounding influences. Secondly, they point to the significantly lower impact speeds that are likely to result in severe injury compared with death - an approximate 10% chance of death at 23 mph (37 km/h) compared with a 10% chance of serious injury at 16 mph (26 km/h). Moreover, Tefft goes on to estimate how average impact speeds differ between cars and light trucks and between an average 30 year old and 70 year old for a given risk of death or severe injury. For the former, a light truck need only collide with a pedestrian at an average impact speed 6.3 mph (10 km/h) lower than for a car for the equivalent risk of severe injury. For the latter, the impact speed involving a 70 year old pedestrian can be 9.3 mph (15 km/h) lower than for a 30 year old pedestrian for a crash outcome of similar severity.

While the above review of the literature regarding the risk of death or serious injury to a pedestrian related to impact speed has been necessarily brief, it is instructive in terms of what we can reasonably glean from the research to date and what factors lie outside the research but are likely to be influential. A related but important finding relates to the relationship between impact speeds and the preceding travel speeds. These findings and their implications are discussed below.

The kinematics of speed and vehicle stopping distance

While the presentation of quantitative information on the kinematics of vehicle stopping distances, as a function of initial travel speed, is not new, it is discussed briefly here because it complements the overall discussion of the role of impact speed on injury risk, and is intended to provide the reader with greater insight.

Figure 5 shows the stopping distance profile for initial speeds of 30, 40, 50, 60, 70 and 80 km/h, for a driver perception-reaction time (PRT) of 1.2 seconds and coefficient of friction of 0.7; both values are regarded as reasonably typical and suitable for this application.

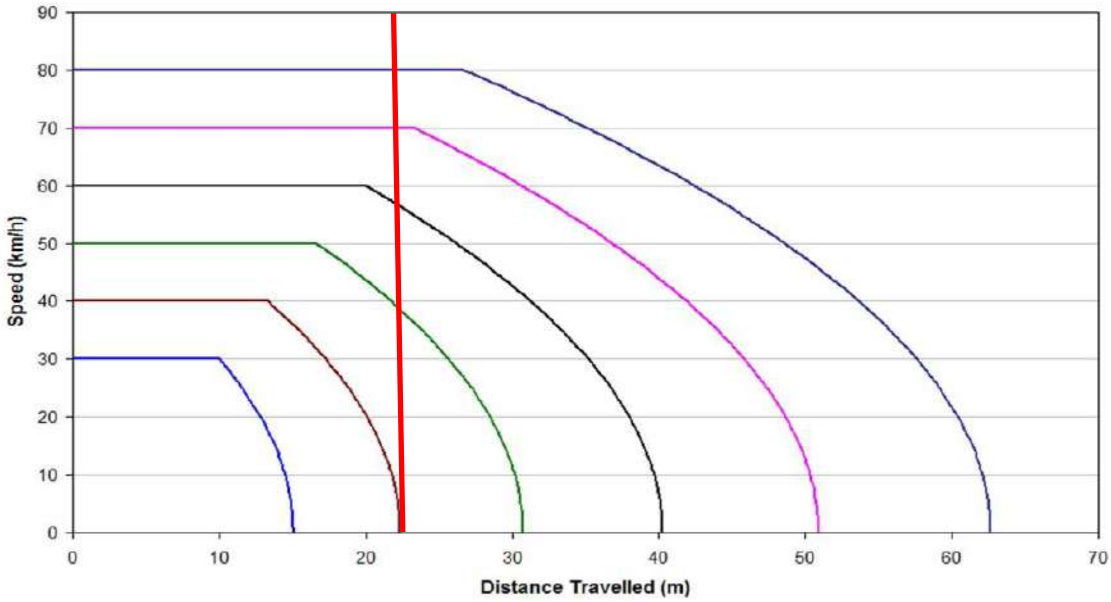

Figure 5: Stopping Distance Profiles for a Range of Initial Travel Speeds

The stopping distance profile is made up of two parts: first, the horizontal part, representing the distance travelled at the initial speed during the driver's PRT and, secondly, the curved part which reveals increasing reduction in speed as a function of distance during the braking phase. To provide a more complete picture on the role of speed, two fundamental points are made regarding Figure 5:

- The stopping distance decreases non-linearly with decreasing initial speed, due to the 2^{nd}-power relationship with speed. For every reduction of 10 km/h in initial speed, there will be *a progressively larger decrease* in stopping distance, meaning that crash risk also falls non-linearly with reductions in initial speed;
- Studying the kinematics of bringing a vehicle to rest shows that half of the initial speed is washed off very late in the braking phase (typically during the last 20 percent of the braking phase). This helps to explain why small increases in initial speed lead to surprisingly large increases in impact speed. To further illustrate this point, the vertical line at the 22 metre mark on the x-axis of Figure 5 shows that:
  - a vehicle with an initial speed of 40 km/h can be brought to a halt within about 22 metres, thereby avoiding a collision with a hypothetical pedestrian;
  - drivers faced with the same hypothetical crash scenario when travelling at higher initial speeds, namely, 50, 60, 70 or 80 km/h would impact a pedestrian at approximately 38, 57, 70 or 80 km/h, respectively, assuming the driver PRT and road frictional characteristics noted above.

It is informative to compare these impact speeds with the risk relationships discussed above.

Discussion of Findings

While much of the research effort to date has been on defining as accurately as possible the shape and position of the curve on the risk vs impact speed axes, it must not be overlooked that there is no meaningful, precise relationship that can be defined.

Firstly, we all differ as individuals in our tolerance to energy exchange in a crash, due to factors such as age, health status, level of impairment due to alcohol or other drugs, physical stature, and stance and orientation at the moment of impact.

Secondly, while cars of the same make and model might be regarded as identical, there still remain major variations within vehicle fleets, with mass and design characteristics such as vehicle height, frontal profile and rigidity determining to a significant extent the severity of injury outcomes.

Thirdly, the crash circumstances and surroundings at the crash location can also be influential in determining injury outcomes. For example, it is common for struck pedestrians to be thrown in the air or to fall directly to the ground following the initial impact with the striking vehicle. The presence of hard surfaces, not capable of deforming during the secondary impact, increase injury risk as a result of high levels of acceleration experienced by the struck pedestrians. Energy absorbing surfaces in high pedestrian areas are now being assessed as a possible means of creating more forgiving surroundings should a crash occur or a pedestrian fall.

Given the very wide array of realistic crash circumstances described above, it is clear that there are innumerable possible combinations that make it meaningless to attempt to define a precise risk relationship. It makes more sense, therefore, to consider the research to date as indicative of the risks faced by pedestrians in general but that some groups will face lower risks on average (e.g., young, healthy males) while other groups will be subject to higher risk (e.g., older pedestrians, especially those with health problems). When viewed in this way, the evidence can guide decisions concerning design and operation both at the level of policies and standards, and at the individual location level where design and operational details must be defined.

The Safe System aspiration is to eradicate death *and serious injury*. Clearly, the threshold for serious injuries, as referenced in the brief literature review above, is much lower than for fatalities, for all age groups. While it understandable that the focus of early work on operationalising the Safe System has been on *fatalities*, mainly because the research-based evidence has been largely focussed on fatalities, it is time to shift the focus to understanding better the serious injury risk relationships with impact speed. Further research is needed in this area. And while the indications are that achieving Safe System speeds for pedestrians may result in unacceptably low speed limits, that is, travel speeds that avoid impacts that produce severe injury for all pedestrians, it should be acknowledged that as speed limits reduce, not only does injury risk fall but so too does crash risk. This means that it may not be necessary, ultimately, to set speed limits at Safe System levels in practice, since crash risk will approach very low levels, thereby making decisions on biomechanically tolerable impact speeds progressively less important.

Increasingly, a number of interventions will need to come into play to achieve high levels of safety for all pedestrians. They all will be aiming to either avoid a collision through separation or, in the event of a crash, to reduce impact speeds to mitigate the risk of severe injury to pedestrians. In the short to medium term, they will include reduced speed limits at locations and in areas where pedestrian exposure and resultant trauma is high in aggregate, infrastructure measures to moderate speeds especially at high-risk conflict points (for example, platform treatments at intersections and for raised pedestrian crossings at mid-blocks with kerb outstands) with supporting enforcement and public education where appropriate. In the longer term, vehicle safety features will increasingly come to the fore – technologies such as ISA (Intelligent Speed Assist) to ensure that drivers keep within posted speed limits and AEB (auto-emergency braking) that will initiate hard braking if the driver doesn't when collision with a pedestrian is imminent.

Conclusion

Much useful research has been conducted to establish relationships between impact speeds and the risk of a pedestrian being killed and, in some cases, being severely injured. Given that impact speed estimates will vary as a result of a range of confounding factors including pedestrian age, stature and level of fitness, vehicle frontal profile and rigidity as well as crash circumstances, outcomes can best be viewed as indicative only for any particular crash circumstance. Safe System principles steer decision-makers towards making conservative decisions with a view to minimising the risk of severe injury or death occurring in the event of a collision. Accordingly, the practitioner needs to call upon a range of measures including reduced speed limits, infrastructure improvements with supporting enforcement and public education where applicable to help ensure safe use of the road network by pedestrians. In the longer term, vehicle technologies such as broader deployment of Intelligent Speed Assist and Automatic Emergency Braking will come to the practitioner's aid.

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Drug Driving in NSW: evidence-gathering, enforcement and education

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Abstract

Drug driving is an area of increased research focus and policy action in NSW. Recent research by Transport for NSW (TfNSW) has identified that 13% of fatalities on NSW roads over the period 2010-13 involved a driver or rider with at least one of three illicit drugs (cannabis, speed, ecstasy) present in their system. This places drug driving alongside other key behavioural factors in the road toll, including alcohol and fatigue.

A recent survey of NSW drivers who use illicit drugs found that 30% self-reported drug driving at some point. This equates to a prevalence rate of 2% of NSW drivers. It also found that drug drivers in NSW are generally not yet convinced of the likelihood of being caught and that many think their drug use does not impair their driving skills.

Work is underway with the NSW Police Force to better understand the available evidence and further deter drug driving. Actions include detailed analysis of laboratory results from drug driving offences and enhanced linkage of drug test and crash data to inform policy development and trends analysis. Roadside drug testing, which has been in place in NSW since 2007, will also be significantly expanded from around 30,000 tests per year to over 90,000 tests per year. Operations are targeted to high risk locations and are increasingly mobile and decentralised to enhance regional enforcement and maximise deterrence.

To support the rollout of enhanced enforcement, TfNSW has commenced development of a communication strategy and public education.

Introduction

In March 2015, the NSW Government announced a threefold increase in roadside drug testing on NSW roads by 2017. This initiative is one part of a package to enhance drug driving countermeasures, which also includes the development of targeted drug driving communications informed by survey research; and an ongoing research commitment to enhancing analysis of drug test results and linkage to NSW crash data. The aim of this paper is to provide a brief outline of recent Transport for NSW research on drug driving, and the new initiatives.

Background

Over the past decade, the focus for NSW drug driving programs has been deterring and detecting drug drivers and riders through on-road enforcement by the NSW Police Force.

Under the *Road Transport Act 2013*, drivers can be charged for driving with the presence of an illicit drug (cannabis, speed, ecstasy, cocaine or heroin) in their system. Drivers in NSW can also be charged with Driving under the Influence (DUI) of an illicit or pharmaceutical drug if they have drugs in their blood or urine, and are driving impaired.

NSW Police commenced roadside drug testing of drivers' oral fluid in 2007. The power to conduct roadside testing supplemented existing Police powers to arrest and blood test drivers believed to be under the influence of drugs.

Roadside testing detects three commonly used illicit drugs only: delta-9-tetrahydrocannabinol, methylamphetamine and methylenedioxymenthylamphetamine (referred to as cannabis, speed and ecstasy). Positive roadside test results are confirmed by laboratory screening of oral fluid samples.

Since introduction, over 250,000 roadside tests have been conducted by NSW Police. Overall, one in 34 drivers have tested positive at the roadside for one or more commonly used illicit drug. Around 1,000 drivers in NSW have been convicted of a drug driving offence (presence or driving under the influence) each year since 2008. To date, communications have played a minor role in supporting Police enforcement, including targeted information for the heavy vehicle industry and the high school curriculum.

Recent NSW research

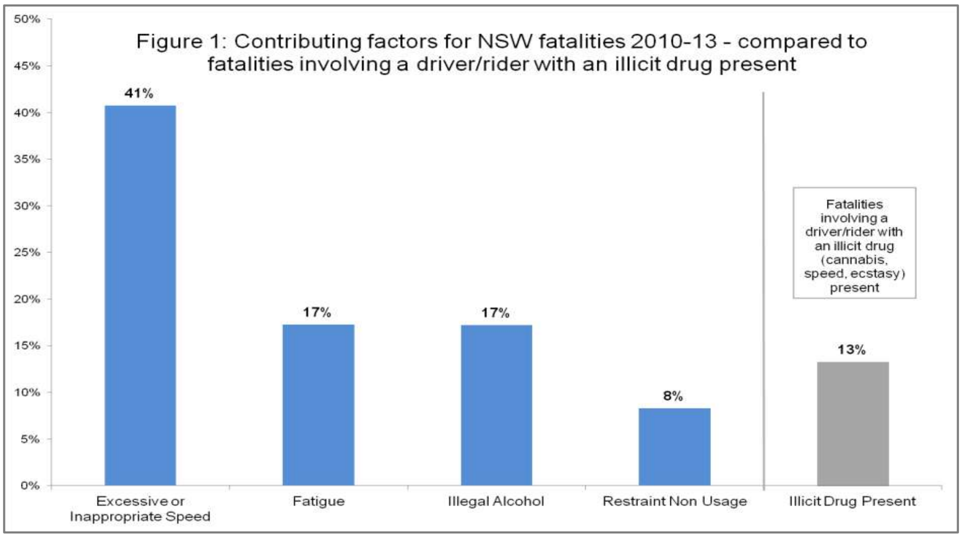
Drug driving and the NSW road toll

Since December 2006, NSW road transport legislation has enabled compulsory drug testing of drivers/riders and supervising drivers involved in fatal crashes. Results have been used by NSW Police to prosecute drivers for drug driving or other serious culpable driving offences but have not, until recently, been linked to NSW crash data for road safety analysis.

In 2014, Transport for NSW obtained and matched test results for drivers and riders involved in fatal crashes over the period 2010-2013 from the Forensic and Analytical Science Services (FASS) of NSW Health. As a first step, results were analysed for the presence of the three common illicit drugs detectable through roadside testing (cannabis, speed and ecstasy).

Over the period 2010 - 2013, 174 fatal crashes (13% of all fatal crashes on NSW roads) involved a driver or motorcycle rider with at least one of the three illicit drugs present in their system. The proportion of NSW fatalities from fatal crashes involving a driver/rider with illicit drugs present in their system has increased slightly over the four year period analysed, from 13% in 2010, to 16% in 2013.

To place this in context with other behavioural factors in the NSW road toll, over the period 2010-2013 illicit drugs were present (in an impairing or other concentration) in a similar proportion of NSW fatalities to illegal alcohol or fatigue; see Figure 1 below.



Drivers/riders involved in fatal crashes with illicit drugs present in their system were more likely to have also engaged in other high risk behaviours, including illegal blood alcohol (25%) or speeding (48%). A majority of the drivers/riders identified were male (86%).

Further analysis is now underway to maximise the completeness of the data set and analyse the extent to which other illicit drugs and misused pharmaceutical drugs are present in NSW fatal crashes and potential impairment of drivers involved in fatal crashes.

Self-reported behaviour and attitudes of NSW drivers who use illicit drugs

In 2014, Transport for NSW commissioned attitudinal research involving NSW drivers to determine the prevalence of drug driving on NSW roads and to explore the attitudes and beliefs of self-reported drug drivers (Taverner Research, 2015). The survey is the follow up to research completed in 2008, shortly after the introduction of roadside drug testing (Taverner Research, 2009).

The 2014 telephone survey sample included over 7,500 NSW licensed drivers. An extended telephone interview was undertaken with a subsample of over 500 drivers who admitted to recent illicit use of drugs (use of a common illicit drug or pharmaceutical drug illicitly in the previous 12 months). Amongst the subsample of NSW drivers who admitted to recent illicit drug use, 30% reported driving after taking drugs at some point in the past. This equates to a population prevalence of 2%.

A similar but separate telephone survey was also recently completed involving NSW drivers who regularly drink alcohol to monitor drink driving behaviour. Overall, 3% of drivers surveyed admitted to driving within the previous month when they knew or suspected they were over the legal alcohol limit (Taverner Research, 2015b). To compare, 13% of NSW drivers who admitted to recent illicit drug use reported drug driving at least once a month. This highlights that while illicit drug drivers represent a comparatively smaller proportion of the population, they report drug driving more regularly than drink drivers report drink-driving.

Illicit drug driving was more prevalent among males and younger drivers (age groups from 16-39 years). There was also a strong relationship between frequency of drug use and frequency of drug driving, with more frequent users (particularly regular users of marijuana) reporting more frequent drug driving. There was no significant difference in the prevalence of drug driving between metropolitan and non-metropolitan respondents.

In general, self-reported drug drivers were less likely to see the risks associated with drug driving, with many (44%) believing that the drugs they take do not diminish their driving ability. Drug drivers also reported being much more willing to be a passenger in a vehicle driven by a driver under the influence.

The survey also found that, while there are high levels of awareness that drug driving is illegal and that Police can conduct drug testing, illicit drug using drivers are not yet convinced that a drug driver is likely to be caught (49%). This is compared to 70% of the same sample who thought it likely that a drink driver would be caught.

These findings highlight the need to enhance the deterrent effect of drug driving enforcement in NSW, as well as shift drug users' beliefs about how drugs affect their driving skills and safety.

Drug driving initiatives

The new research has provided an evidence base to enhance drug driving countermeasures in NSW. Leveraging the success of past strategies to address drink driving, NSW has now adopted an integrated general deterrence approach to drug driving that combines high visibility police enforcement with public education.

Further research will also inform a review of NSW drug driving policy and legislation to ensure that offences and penalties are appropriate to deter drug driving and address emerging issues.

The new initiatives are being delivered by Transport for NSW in consultation with a drug driving consultative group comprised of key NSW Government agencies. The consultative group enables a whole-of-government approach that will ensure related government policy development and programs are also considered in future drug-driving review and reform. Key initiatives include:

Strengthening NSW Police enforcement

By 2017, the number of roadside drug tests in NSW will reach over 97,000 tests per year. Deterrence will be maximised through an increasingly decentralised and mobile approach to enforcement. New drug testing devices are being rolled out to police stations across NSW to enhance enforcement capability in regional and rural NSW. Portable initial drug testing wipes are being made available to trained officers in patrol vehicles to enable 'mobile' enforcement.

From February 2015, legislative enhancements to the *Road Transport Act 2013* also came into effect to expand the circumstances in which Police may order a sobriety assessment and blood test if they suspect a driver is under the influence of a drug. NSW Police can now require this test if a person's appearance, behaviour or manner leads them to suspect the driver may be under the influence.

These changes will significantly enhance the visibility and increase the unpredictability of drug testing, providing more deterrence from enforcement.

Developing a new drug driving communications strategy

To enhance the general deterrence provided by the expanded roadside drug testing regime, and increase community awareness and social unacceptability of drug driving, Transport for NSW is developing a broad based communications strategy.

This will include a state-wide public education campaign, based on behaviour change principles and insights from recent attitudinal research and crash analysis. The rollout of the campaign will be timed to coincide with staged increases in NSW Police enforcement over the period from 2015 to 2017.Work is also underway to develop targeted communications for high risk groups and to enhance school based education materials delivered as part of the NSW high school curriculum.

Enhancing analysis of drug test results and linkage to NSW crash data

Transport for NSW is working closely with the NSW Police to enhance the analysis of results from roadside oral fluid testing, blood and urine testing from fatal crashes and drug driving offences, and to interpret test results linked to crash information.

This research partnership will provide a detailed report of drug driving on NSW roads over time, and will explore the potential road safety impact of illicit, emerging, synthetic and pharmaceutical drugs. This information may also enable strategic deployment of drug enforcement operations to high risk areas.

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Impulsivity and Aggression in Young Drivers Assessed in Short Driving Simulator Scenarios

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Abstract

Interactions between gender, impulsivity, and driving anger, and young people's driving behaviour were assessed in an immersive driving simulator. Personality measures included the Impulsivity Questionnaire, the Driving Anger Scale, and the Driving Anger Expression Scale. Five short driving scenarios were used: T-junction gap acceptance, following distance, approaching amber traffic lights, merging following traffic lights, and overtaking. Two forms of each scenario were created: a provocative ("hot"), and a matched neutral ("cool") form. For example, in merging lanes following a traffic light scenario, in the hot form, a car in the other lane would "race" the participant's vehicle to the merge point; in the cool form, the other vehicle would merge in a more orderly fashion. Dependent variables comprised difference scores derived from the vehicle dynamics data between the hot and cool driving scenarios. From an initial screen of 278 participants 52 (55% female; age *M* = 19.13 years) were selected, half of whom had high impulsivity and anger scores, while the other half had low scores on both these measures. Results included main effects for Gender, and Impulsivity, and a Gender, Impulsivity, and Driving Anger 3-way interaction. Overall, young impulsive males had a higher tendency for risky driving than females did. However, high impulsivity, low driving anger males exhibited risky driving behaviour differently, suggesting the influence of other motivational factors, such as venturesomeness.

Introduction

In the 12 months ending June 2015, persons aged 17-25 years comprised approximately 13% of Australia's population, while accounting for just over 21% of motor vehicle accident deaths (Department of Infrastructure and Regional Development, 2015). As driving behaviour directly affects crash outcomes, motivations associated with young persons' driving behaviour are likely to be relevant to informing safe driver interventions targeting this demographic. Factors affecting driving behaviour include personality (Constantinou et al., 2011), with impulsivity and anger (expressed as aggression) known to have potentially adverse consequences for road safety (Bina, Graziano, & Bonino, 2006; Dahlen, Martin, Ragan, & Kuhlman, 2005; Deffenbacher et al., 2003; Jonah, 1986; Jonah, Thiessen, & Au-Yeung, 2001). Compared with older drivers, young drivers have been observed being more likely to drive faster, to exceed speed limits, and to drive closer to a lead vehicle (Glendon, 2007; Glendon & Sutton, 2005). They also accept narrower gaps when merging, and are more likely than older drivers to accelerate when approaching an amber light (Jonah, 1986). Younger drivers also have a propensity to weave through traffic and to pass other vehicles more frequently than older drivers do (Jonah et al., 2001), while young male drivers are more likely to run red lights (Hemenway & Solnick, 1993). It has been concluded that young male drivers' failure to maintain a safe following distance and engage in illegal passing could be attributed to their propensity for aggressive driving (Claret et al., 2003).

Dahlen et al. (2005) found that impulsivity in young people contributed to predicting risky and aggressive driving behaviour, particularly using the vehicle to express anger. Compared with their non-accident-involved counterparts, male adolescents who reported a motor vehicle accident-related injury had higher scores on measures of impulsivity, inattention, conduct problems, and emotional lability (Jelalian et al., 2000). Deffenbacher, Lynch, Oetting, and Swaim (2002) found that trait driving anger was strongly related to self-reported aggressive driving behaviour, and that compared with females, males' manifestations of anger were associated with greater risk taking and aggressive expression while driving. González-Iglesias et al. (2012) found that males expressed greater anger at police presence, while females expressed greater anger at traffic obstructions. Other sex differences in anger expression included females exhibiting a more adaptive attitude. An evident gap in the literature is the extent to which sex-related anger differences might extend to a wider range of driving schemas. Sex differences across a number of contrasting traffic scenarios are therefore a focus of the current study.

Driving behaviour was assessed in a driving simulator in matched driving scenarios: one being a "cool" version, in which another vehicle's movements and traffic conditions were designed as being unlikely to provoke aggressive and/or impulsive driving. In contrast the corresponding "hot" scenarios were designed to provoke such behaviour. In their driving simulations, both Richer and Bergeron (2012), and Duan, Li, and Salvendy (2012) showed how the behaviour of other vehicles can elicit risky driving in young people. Simulated driving offers the opportunity to study driving behaviours in a risk-free environment, also allowing for experimental control over, and manipulation of, driving scenarios. Laboratory-based study can also include measures of personality factors known to influence driving outcomes, which for ethical, safety, and practical reasons, could be neither generated nor manipulated in naturalistic studies (Yan et al., 2008).

Method

Participants and measures

A convenience sample of Griffith University School of Applied Psychology students (*N* = 278, 73% female, mean age 20.1 years) possessing either a Learners, or a Provisional, or an Open driving licence completed two questionnaires: Eysenck's (1985) I_7 Impulsiveness Questionnaire (I_7), and Deffenbacher, Oetting, and Lynch's (1994) Driving Anger Scale (DAS), before undertaking any simulated drives. The I_7 has three subscales measuring Impulsivity, Venturesomeness, and Empathy. Reported Cronbach's α for the I_7 impulsivity scale were: males .84, and females .83 (Eysenck et al., 1985). The DAS is a 33-item self-report questionnaire which measures the intensity of anger experienced on six subscales: hostile gestures (3 items, example: "Someone honks at you about your driving"), illegal driving (4 items, example: "Someone is weaving in and out of traffic"), police presence (4 items, example: "A police officer pulls you over"), slow driving (6 items, example: "Someone is slow in parking and holding up traffic"), discourtesy (9 items, example: "Someone is driving right on your back bumper"), and traffic obstructions (7 items, example: "You are stuck in a traffic jam"). Participants were asked to rate the amount of anger they experience regarding specific driving situations on a scale from one (*none at all*) to five (*very much*). Possible scores ranged from 33 to 165. All items are summed for an overall score. Reported Cronbach's α for the DAS was .90 (Deffenbacher et al., 1994). From screening the initial participant sample, two groups were selected for participation in the driving simulator study. Participants were aged between 17 and 24 years and lacked motion sickness susceptibility as determined by Golding's (1998) MSSQ. One group (13 females, 12 males) consisted of participants scoring high on impulsivity (> 8), anger (> 142), or both; the other group (14 females, 13 males), scored low on these measures (impulsivity < 6; anger < 78). Informed consent was obtained from all participants and the research complied with Griffith University's Human Research Ethics approved protocol (PSY/D8/10/HREC).

Equipment

A fixed-base, immersive driving simulator was used to measure driving behaviour. Driving scenarios, which included a secondary intelligent vehicle (IV), were created using OKTAL SCANeR™ studio 2.1 software. Images were projected via a Christie® Mirage HD6 1080 DLP onto an Immersaview double curvature screen, 2.2 metres high and 3.2 metres around. Participants interacted with the simulated virtual environment via Logitech® G27 wheel and pedals module with a Logitech Evolution® Playseat positioned so that the participant's head was 2.0 metres from the screen. Simulated vehicle dynamics measured on a number of parameters were sampled twenty times a second and stored for analysis using the SCANeR™ software. The human interactive vehicle (HIV) was always simulated as having automatic transmission.

Short Driving Scenarios

"Hot" (provocative) and "cool" (non-provocative) versions of five traffic scenarios were created. These paired scenarios were designed to differentiate participants' driving behaviour resulting from impulsive and aggressive driving decisions under provocation from their "normal" driving behaviour, that is, without provocation. Each trial lasted approximately 30–45 seconds with no speed limits indicated in the scenarios.

T-junction Gap Acceptance

On a single-lane road, the HIV began positioned at a T-intersection ready to turn left. The view of the road was towards the oncoming traffic from the right at a constant speed of 60 km/h until the participant moved off and turned left to merge. The hot scenario comprised a series of smaller gaps (of 3, 5, 4, 5, 4, & 7 seconds), while the cool scenario comprised fewer but larger gaps (of 6, 9, & 12 seconds) between vehicles. A lack of feasible gaps may compromise a driver's patience leading them to accept a smaller gap. Alternatively, a larger gap detected further away may result in a driver dismissing an acceptable gap in order to accept a later, larger, and more favourable gap.

Following Distance

This scenario assessed the risky driving behaviour of close following. On a single-lane road**,** the HIV began positioned 70 metres behind the IV, which was programmed to travel at the same speed as the HIV up to 80 km/h, at which point it maintained a constant speed. In the cool scenario, the IV continued at 80 km/h regardless of the HIV driver's behaviour. In the hot scenario, in the event that the HIV driver accelerated to be within 66 metres (safe travelling distance), the IV provocatively braked and decelerated to 60 km/h.

Amber/Red Traffic Light Acceptance

The HIV began either 190 metres (cool trial) or 250 metres (hot trial) from a set of traffic lights. The traffic lights were programmed to change from green to amber when the HIV driver was either 140 metres (hot trial), or 80 metres (cool trial) away. Duan et al. (2012) found that at three seconds' duration, if a driver braked, then they would stop at the intersection as the lights turned red, whereas if a driver accelerated then they would just pass through the intersection as the lights turned red. In the current study, consistent with most Queensland traffic light intersections, the amber light appeared for four seconds so that the critical time for passing through traffic lights was four seconds (approximately 78 metres driving at 60 km/h). A driver who accelerated rapidly to drive through the amber light from a distance representing more than four seconds, would thereby generate a different driving celeration profile from a driver who steadily decelerated to a stop.

Merging Following Traffic Lights

This task was set on a dual-lane road where the left lane ended 75 metres after a set of traffic lights. The HIV began positioned at the left lane at the traffic lights (red) with the IV in the right lane. In the cool scenario, the IV was programmed to accelerate steadily and proceed at 60 km/h. In the hot scenario, the IV was programmed to continue at the same speed as the HIV, thereby being positioned directly alongside the HIV (the intelligent vehicle's bonnet was visible, see Fig. 1), until a short distance from the lane merging, at which point the IV accelerated past the HIV driver. In the latter (hot) scenario, the escalating competition for road space might be expected to provoke aggressive driving behaviour.

Overtaking

The HIV began positioned 70 metres behind the IV on a dual lane road. In the cool scenario, the IV was programmed to travel at the same speed as the HIV up until 80 km/h, at which point it maintained a constant speed. In the hot scenario, in the event that the HIV driver accelerated to be within 66 metres (safe travelling distance) of the IV, the IV was programmed to brake and decelerate to 60 km/h. If the HIV driver attempted to overtake, then the IV was programmed to continue at the same speed as the HIV, thereby being positioned directly alongside the HIV (the IV's bonnet was visible on the left) so that the participant was unable to move back into the left lane. If the HIV driver attempted to gain on the IV, again there would be competition for road space and an opportunity for further displays of aggressive driving to be evoked (see Fig. 2, Richer & Bergeron, 2012). This scenario again assessed drivers' competition for road space in a slightly different environment from the merging scenario, while similarly distinguishing participants' behaviour resulting from impulsive and aggressive driving decisions.

Figure 1. The screen shot on the left shows the start of the merging lanes scenario at the traffic lights: the instrumentation and instructions are displayed on the screen. The screen shot on the right shows the hot scenario near its end where the IV is winning the race to the merge point.

Figure 2. The screen shot on the left shows the start of the overtaking scenario with instructions. The overtaking scenario in progress is shown on the right. The car ahead is the IV.

Procedure

Participants were familiarised with the driving simulator, the on-screen instructions and instrumentation, and were allowed to practice operating the HIV within the T-junction and following distance scenarios without feedback until they reported feeling comfortable with the controls. This normally took about five minutes. Participants were then informed that there would be 20 scenarios, each lasting for approximately 30-45 seconds, and that a black screen would appear between each scenario, with a break provided after the first ten trials. It was explained that participants would be required to operate the HIV from a stationary position each time and as far as possible to "drive" as they normally would in an actual vehicle. Each of the ten scenarios (five scenarios × "hot" and "cool" conditions) was repeated and presented in a unique randomised trial order for each participant so as to eliminate order effects. Each simulator session lasted about 55 minutes.

All participants were tested blind by the second author. At the end of the testing session, they completed Deffenbacher's et al.'s (2002) 49-item Driving Anger Expression Inventory (DAX). Cronbach's α for total aggressive expression (verbal, physical, & vehicular) has been reported as .90 (Deffenbacher et al., 2002). The DAX was included as a self-report measure to assess driving anger just within the simulated driving behaviour.

Results

Data from the initial participant screen (N = 278) yielded a positive correlation between Impulsivity and Driving Anger (r = .28, p < .001). There were no significant differences between males and females on either Impulsivity or Driving Anger.

HIV dynamic measures obtained via the OKTAL SCANeR™ studio 2.1 software used for each scenario are outlined in Table 1 (cf. Yan et al., 2008). The dependent variables (DVs) were difference scores [(Hot 1 + Hot 2) – (Cool 1 + Cool 2)] computed for each of these measures. Using difference scores meant that each participant acted as their own control. Driving behaviour at baseline (cool scenarios) could then be compared with that in provocative traffic/environmental conditions (hot scenarios). A few participants were not included in the analyses due to their data being univariate outliers, and/or reporting motion sickness, headache, or lack of vigilance during testing.

Correlations were calculated for each scenario to test relationships among vehicle dynamic difference measures and personality factors. For the Amber Traffic Light scenario, Impulsivity was negatively correlated with Acceleration@Amber Light (r = -.33, p < .05), and for the Overtaking scenario, the DAS correlated with Lane Position SD. All correlations between the DAS and DAX, and Impulsivity and DAX were significantly positive, indicating that participants' expressed driving anger feelings in the simulated environment, as assessed by the DAX (i.e., state anger measure), were similar to dispositional driving anger and impulsivity, as assessed by the DAS and I_7.

Three-way between-groups MANOVAs were performed on DVs in each scenario to investigate the effects of Impulsivity, Driving Anger, and Gender differences on driving behaviour. Age was included as a covariate. The Overtaking scenario yielded significant results on the combined DVs to reveal main effects of Gender, $F(4, 28) = 5.41$, $p = .002$, $\eta^2_p = .44$, and Impulsivity, $F(4, 28) = 2.97$, $p = .037$, $\eta^2_p = .30$, and a 3-way Impulsivity × Anger × Gender interaction, $F(4, 28) = 5.40$, $p = .002$; $\eta^2_p = .44$. In further analysis of each DV in the same scenario, the Impulsivity× Anger × Gender interaction was significant for acceleration noise, $F(1, 31) = 12.15$, $p = .001$, $\eta^2_p = .28$, and for maximum speed, $F(1, 31) = 20.82$, $p < .001$, $\eta^2_p = .40$. Males who were high on Impulsivity and low on Driving Anger demonstrated greater differences than any other group between hot and cool scenarios for both variables. In contrast, males who were high on Impulsivity and high on Driving Anger demonstrated the lowest differences in acceleration noise, with a similar pattern being obtained for maximum speed. Females who were low on Impulsivity and high on Driving Anger demonstrated the lowest differences in maximum speed between hot and cool trials (see Figs. 3 & 4).

The main effect of Gender was significant for acceleration noise, $F(1, 31) = 9.98$, $p = .004$, η^2_p = .24; compared with females, males demonstrated greater differences in acceleration noise between hot and cool scenarios. There was a main effect of Driving Anger for maximum speed, $F(1, 31)$ =

7.33, p = .011, η^2_p = .19; participants with a higher predisposition for Driving Anger demonstrated smaller differences in maximum speed compared with those low on Driving Anger.

Table 1: Dependent Variables for each Scenario[1]

T-Junction Gap Acceptance Scenario	
Acceleration Noise	Fluctuation in acceleration whilst undertaking the manoeuvre
Maximum Speed	Maximum speed of HIV driver whilst making the manoeuvre
Following Distance Scenario	
Acceleration Noise	As above
Maximum Speed	As above
SD Lane Position	Amount of movement back-and-forth across the lane; greater movement may be indicative of frustration at a slow lead vehicle
Time to Collision	Relative stopping distance between HIV and IV, where smaller values may be indicative of frustration at a slow lead vehicle
Rate Deceleration @ 80 km/h	Responsiveness of HIV driver to reduced rate of acceleration of IV ahead once it reached 80 km/h
Amber/Red Traffic Lights Scenario	
Acceleration Noise	As above
Maximum Speed	As above
Acceleration @ Amber Light	Difference in rate of acceleration in the moments preceding, and the moments following, appearance of the amber light
Merging Following Traffic Lights Scenario	
Acceleration Noise	As above
Maximum Speed	As above
Acceleration @ LANEX	HIV driver's rate of acceleration at the point at which they merge from the left lane into the right lane
Overtaking Scenario	
Acceleration Noise	As above
Maximum Speed	As above
SD Lane Position	As above
Time to Collision	As above
Attempted to overtake[2]	Whether HIV merged into right lane in an attempt to overtake the IV ahead in the left lane

[1]All DVs were calculated as difference scores between hot and cool trials.
[2]Dichotomous variable, which was not included in MANOVAs.

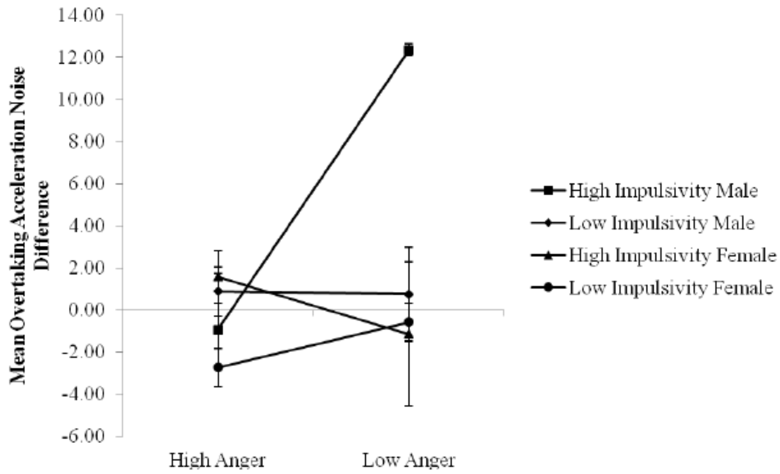

Figure 3. Overtaking scenario. Mean Acceleration Noise difference scores by Gender, Impulsivity, and Anger. Error bars are ± 1 SEM on this and all subsequent graphs.

There was a main effect of Impulsivity for acceleration noise, $F(1, 31) = 6.94$, $p = .013$, η^2_p = .18, such that those with a greater predisposition for Impulsivity demonstrated greater differences in acceleration noise than did those low on Impulsivity. In the other scenarios, only the Merging Following Traffic Lights scenario produced significant results for individual DVs. There was a significant interaction between Driving Anger and Gender for maximum speed, $F(1, 31) = 7.41$, p = .011, η^2_p = .19; such that males who were low on Driving Anger demonstrated greater differences in maximum speed between hot and cool trials, while females who were low on Driving Anger demonstrated negative differences (see Fig. 5). Interestingly, both males and females who were high on Driving Anger demonstrated minimal differences in maximum speed. For females, in the Following Distance scenario, Gender was significant on time to collision difference, F (1, 31) = 6.71, p = .014, η^2_p = .18, such that males exhibited negative differences in time to collision between hot and cool scenarios.

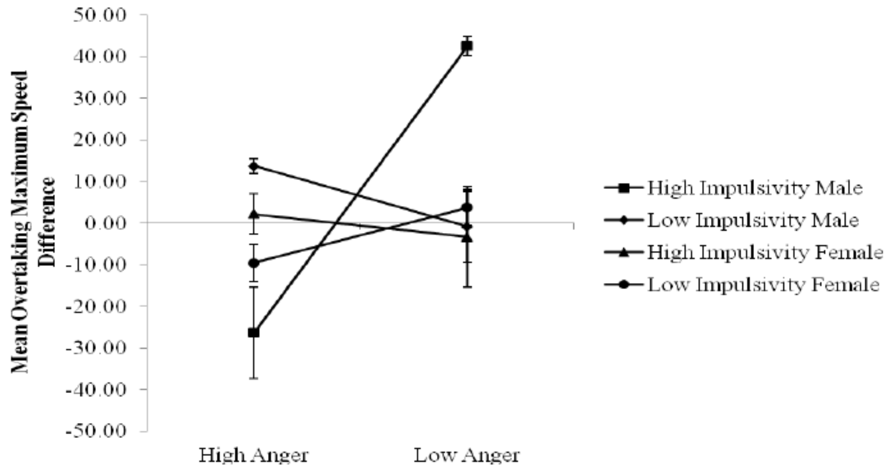

Figure 4. Overtaking scenario. Mean Maximum Speed difference scores by Gender, Impulsivity, and Anger.

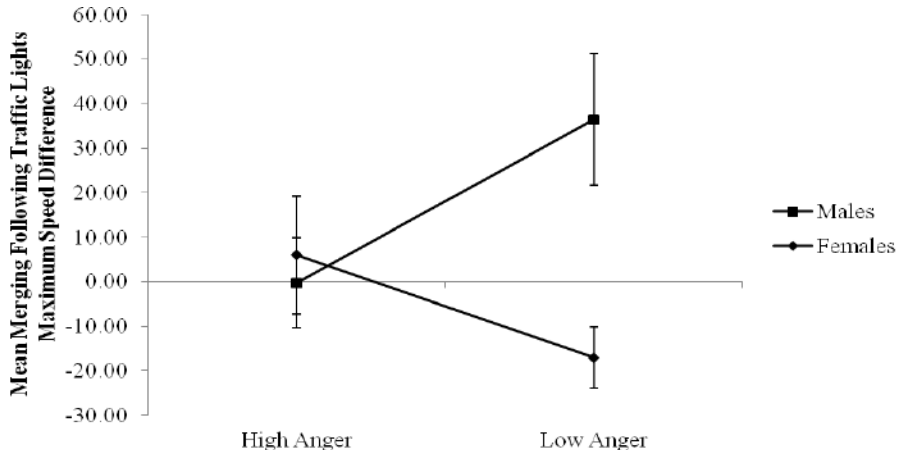

Figure 5. Merging Following Traffic Lights scenario. Mean Maximum Speed Difference scores by Gender and Anger.

Discussion

The significant effect for Impulsivity on overtaking manoeuvres indicated that with greater emotional regulation, young drivers exercised greater caution towards provocative behaviour of the IV in this scenario. On the other hand, driving anger did not have such a clear effect on risky driving, with males and females exhibiting different patterns of behaviour as a product of Impulsivity and Driving Anger. Overall, males showed significantly greater mean difference values than did females, which suggested that male participants were particularly susceptible to provocation by the behaviour of other drivers. In particular, the hypothesis that males demonstrated significantly riskier driving behaviour than females did was supported by significant main effects of Gender for both the overtaking MANOVAs and the between-subjects effect for overtaking acceleration noise. The fact that females' mean difference values were close to zero, or even negative, suggested that they were more consistent in their driving behaviour, and might be expected to exercise greater caution or even submission in provocative on-road situations.

While the driving simulator enabled a high degree of control over the scenarios and highly accurate measures of participants' driving behaviours across identically programmed scenarios, an inevitable limitation was that the ecological validity of this methodology was not assessed in this study. However, Wang et al. (2010) found that visual attention and task measures mapped very closely between simulated and naturalistic driving environments. Nevertheless, because a driving simulator study practically involves zero risk to participants, it remains the case that interpretation of findings from this study is premised on the assumption that driving behaviour exhibited in a driving simulator is a reliable indicator of on-road driving behaviour.

Two of the scenarios developed in the current study suggested that this novel methodology of comparing matched hot and cool scenarios could yield important results, especially for males. Road safety implications of the findings might include: devising vehicle-activated roadside signage messages that target impulsivity and anger issues at locations shown by the study to be critical (e.g., where merging traffic occurs, and where overtaking presents a particular hazard). Such an intervention has been initiated as a pilot, and evaluated by the Queensland Department of Transport and Main Roads (Queensland Government, 2012). Peer influence on adolescent risk taking is well established (Albert, Chein, & Steinberg, 2013), and there is evidence that peer passengers can impact young drivers' behaviours, including speed choice and following distance in both simulated (Lenné, Liu, Salmon, Holden, & Moss, 2011), and naturalistic driving (Hutton, Sibley, Harper, & Hunt, 2002). For both young drivers and their passengers these issues might be addressed using media (e.g., TV) vignettes that capture the essence of the current findings (e.g., a young male driver about to behave impulsively when seeking to overtake where it is unsafe to do so, and being advised by a passenger mate to be patient). In a literature review of novice driver training methods, although Beanland, Goode, Salmon, and Lenné (2013) determined that effects of simulator training on road safety remained inconclusive, these authors identified simulator training as having some impact on driving skills. Thus, Following Paaver et al. (2013), brief simulator-based interventions as part of a driver education program, taking into account personal psychological risk factors, which differ between males and females, may have a role driver training.

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Crash Scene Investigation – The Science of Motion

Applying the Year 10 Science Curriculum to Reduce Crash Outcomes

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Abstract

The South Australia Police Road Safety Centre has developed a 90 minute Year 10 road safety product "Crash Scene Investigation - The science of motion", which is based upon the middle school science curriculum ‘science of motion’ unit of work.

Traditionally, road safety education (RSE) lesson plans are written to address the required learning outcomes and then links to the school curriculum are identified. For some schools, there is no other nexus with the student’s education and RSE is delivered as a ‘stand-alone’ product. The ‘science of motion’ is a standard Year 10 unit of work under the National Schools Curriculum. Crash Scene Investigation is delivered as a lesson within this larger unit of work and provides natural world examples of how the formulae learned in the classroom are applied to practical, vehicle crash, scenarios. The presentation uses Newton's three Laws of motion to explain vehicle and occupant behaviour in a collision. The formula for kinetic energy and its crash implications is explained, as are other formulae such as the speed of light and the co-efficient of friction. Starting with the curriculum and then identifying road safety links, represents a fresh approach to designing RSE programs for secondary school students.

Being the age group most likely to crash and the group most likely to drive older vehicles, the package uses current ANCAP crashworthiness research and (authorised) video footage to demonstrate how vehicles respond to collision forces, including how the structure of a vehicle can have the capacity to prevent energy being transferred to the occupants. Crash scene reconstruction software is used to create an animation of a crash, by using data obtained from the scene and applying basic laws of physics.

A driving simulator is used to allow students the opportunity to safely participate in a number of driving tasks, whilst being distracted. The session is interactive and, through discussion, encourages students to develop social competence and resilience rather than the session being purely information based.

Introduction

People aged 16 to 19 make up 5% of the population, but account for 12% of all fatalities and serious injuries in South Australia, with a rate of 12 deaths or serious injuries for every 10,000 licensed drivers. Risk taking and extreme behaviour are often identified by the media as a key factor in crash statistics, but "research shows that in South Australia over half of all fatal crashes, and 90% of injury crashes, are the result of mistakes, inattention or common lapses in judgement." (Government of South Australia, 2011)

Vehicle safety technology has a significant role to play in the incidence and severity of road crash outcomes; however, a study of South Australian vehicles with an ANCAP star rating, revealed that the state fleet has an average star rating of only 3.78. (Anderson, 2012, p37).

Young drivers have high crash rates, particularly in their first 12 months of unsupervised driving, yet typically the safety level of their chosen vehicle does not appear to be the first priority. (Anderson, et al., 2013) As a demographic that would benefit from safer vehicle technologies and vehicles with a high crashworthiness rating, it is interesting that "little information is available on the factors that go into family decisions about which vehicles teenagers drive." (Rivara et al., 1998)

An examination of the implications of vehicle choice and the potential safety benefits for young driver crashes across Australia and New Zealand identified that, by providing young novice drivers with vehicles with the best crashworthiness rating, "the estimated reduction in serious injuries and fatalities was approximately 86% for young Australian drivers." (Whelan, et al., 2009, p77)

Crash scene investigation – the science of motion, was developed to fit within the middle school science curriculum, as a means of communicating the road safety benefits of safer vehicles to both parents and Year 10 students at a point in time prior to the acquisition of a vehicle.

Methods

Prior to delivery of the program, teachers are provided with links to a series of printed and video PDplus teacher resources prepared by the Science Institute RiAus.

Newton's Laws

Newton's three Laws of motion are used to explain the behaviour of energy, the effects of mass and acceleration and to identify that energy is not lost in a collision. The formula for kinetic energy is used to discuss the fact that substantial increases in impact forces are achieved through relatively small increases in velocity. The speed of light, used in speed detection, the effects of rigidity in relation to energy transfer and the co-efficient of friction are also explored. Whilst the primary focus of this session is to demonstrate the application of the formulae, the session also creates a perception of the relevance of, and need for compliance with, contemporary road laws.

Safer cars

The presentation uses current crashworthiness research from the Australasian New Car Assessment Program (ANCAP) to demonstrate how vehicles respond to collision forces and the relatively low speeds at which some collision types are tested. Data obtained from crash scenes is used to reconstruct the collision, using the same formulae that students have learnt in their science of motion topic. Data such as mass, friction, impact damage, photographs and measurements are used to create a computer generated simulation of a particular crash in which students are able to observe the crash from several different camera angles.

Distraction

Each year, over six hundred young people aged 16 – 19 years are injured on South Australian roads, with distraction being a well-recognised contributing factor. A driving simulator is used to replicate real world outcomes which can result from driving whilst distracted. The on-screen view available to the driver is projected onto a wall/large screen for the student audience to observe.

Parent night

Parents attend an information night in which their preparedness for the driver education task ahead is explored. The session includes a discussion on Road Rule knowledge, attitude and example setting, choosing a driving instructor and buying a safer vehicle.

Results

Table 1. Initial student feedback on vehicle choice, behaviour and risk perception.

	Strongly disagree	Disagree	Agree	Strongly agree
I understand the importance of choosing the safest car	0.33% n = 1	0.99% n = 3	27.06% n = 85	71.62% n = 217
I understand the importance of limiting risky behaviour to keep myself and passengers safe in a vehicle	0.33% n = 1	0.33% n = 1	14.85% n = 45	84.49% n = 256
I understand the concepts of hazard perception and risk	0.33% n = 1	0.33% n = 1	44.88% n = 136	54.46% n = 165

identification				

Discussion

Not every teenager will want to engage in driving at the earliest opportunity and perhaps, from a road safety perspective; this may be the best option. For those who will take up early licensure, there are a number of considerations which will impact on overall crash risk, such as frequency of use and distance travelled. That notwithstanding, providing a young driver with access to the safest car in the household has the capacity to significantly reducing the incidence and severity of road crashes.

Future directions include reviewing the delivery strategy so as deliver the program a little later in the term, when students have undertaken more of the unit of work. It was noted that some students struggled with content when they had not already been exposed to the basic concepts. Expanding the number of sessions to schools across the State and promoting deeper engagement with parents are also areas for development.

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Monitoring changes from 1999 to 2014 in the amount of supervised driving experience accrued by Victorian learner drivers

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Abstract

Newly-licensed drivers are over-represented in crashes. As higher levels of learner supervised driving are associated with a decreased crash risk post-licensing, road safety stakeholders have actively encouraged increased amounts of supervised driving since the mid 1990's in Victoria, Australia. VicRoads introduced a mandatory minimum 120 hours supervised practice whilst on a learner permit in 2007.

The Victorian Learner Monitor survey has tracked changes in driving experience (both supervised practice and lessons with professional instructors) accumulated by different learner permit holders across the years 1999, 2000, 2004, 2005, 2007, 2008, 2009, 2010 and 2014. Each survey year, around 1300 Victorian learner drivers at different stages of learning to drive are surveyed, as well as 200 newly-licensed Victorian drivers.

A study was undertaken to analyse changes in learner driver experience since the first wave of the Learner Monitor survey in terms of a) progress in achieving the minimum target of 120 hours practice over the entire permit period and, b) progress in increasing weekly driving practice - both the likelihood of such practice in every week and the average practice time in those weeks where there is some practice.

This paper presents key findings from this study. Those aged 16 years at learner permit acquisition are now averaging 137 hours of practice. Those aged 17 at learner permit acquisition are now averaging 127 hours of practice. The results are discussed in terms of which learner subgroups require more targeted interventions to achieve the minimum supervised learner 120 hour practice target in Victoria.

Introduction

Newly-licensed drivers are over-represented in crashes. Crash risk is particularly high during the first 12 months of unsupervised driving. A Graduated Licensing System (GLS), which includes supervised learner driving, is a recognised countermeasure to decrease novice driver crashes (Senserrick & Williams, 2014). Research has shown a relationship between higher levels of supervised driving as a learner driver and reduced crash risk once licensed. In a Swedish study, learner drivers who made use of a longer learner period experienced about a 40% reduction in crash risk compared with learner drivers who did not. The longer learner period resulted in learners obtaining more supervised practice. Learners who made use of the longer permit period accumulated on average, 118 hours of supervised practice. Learners who did not make use of the longer permit period accrued, on average, only 41 or 47 hours of practice (Gregersen, 1997; Gregersen et al., 2000).

Over the past 20 years, in Victoria, there has been an active campaign to increase the amount of supervised driving experience accumulated by learner drivers in order to improve novice driver safety. An update to Victoria's GLS followed in 2007 and 2008. One of its aims is to encourage learners to maximise the depth and breadth of their supervised driving experience. The relevant GLS components include:

- a minimum learner permit age of 16 years
- the requirement for learner drivers to accrue a minimum of 120 hours (including at least 10 hours at night) of supervised driving practice (if aged under 21 at licensing) and to record their practice in the approved VicRoads log book
- a minimum learner permit holding period of 12 months for those acquiring a licence when aged less than 21
- a minimum licensing age of 18 years.

These are all components of the ‘exemplar model’ of the Australian GLS policy framework, which was endorsed by Commonwealth, State and Territory Transport Ministers in late 2014 (Senserrick & Williams, 2014).

A preliminary evaluation indicates the revised Victorian GLS has been effective in reducing novice driver crashes. For example 23% fewer first year drivers aged 18 to 20 years (i.e., those expected to be most affected by the new GLS) were found to be involved in all casualty crashes compared with a control group of full licence holders aged 26 to 38 years at the time of analysis (i.e., those not expected to be affected by the new GLS) (Healy et al. 2012).

This paper presents the changes in experience (professional lessons and supervised practice) over the last 15 years in terms of a) progress across the surveys in achieving the minimum target of 120 hours practice over the entire permit period b) progress across the surveys in increasing weekly driving practice, both the i) likelihood of such practice in every week and ii) average practice time in those weeks where there was some practice. The method and results discussed in this paper originate from the report by Swinburne University of Technology, *Learner Driver Experience Monitoring 2014 – Statistical Report* (Meyer, Cunningham, & Rajendran, 2014a).

Females, learners residing in Melbourne, and those who obtained their learner permit at the age of 17 or older were identified in the first 1999 Learner Monitor report as averaging fewer hours of practice than other subgroups. Those who obtained their learner permit at the age of 17 averaged particularly low levels of supervised practice. Therefore changes in total hours of practice for these subgroups are of special interest in this research (Meyer, Cunningham & Rajendran, 2014b).

This research, which aims to determine if changes in practice hours across surveys conducted since 1999 have been statistically significant, is part of the final evaluation of the Victorian GLS, and will assist in determining its effectiveness. The results from the Learner Monitor surveys are discussed in relation to which subgroups require more targeted interventions to achieve the supervised learner 120 hour practice target in Victoria, the relationship to licensing trends and the effectiveness of the GLS in terms of learners obtaining the required practice hours.

Method

The survey

Since 1999, the Learner Monitor telephone survey has measured the supervised driving and driving lesson experiences of a representative sample of Victorian learner permit holders. Surveys have taken place in 1999, 2000, 2004, 2005, 2007, 2008, 2009, 2010 and 2014.

These cross-sectional surveys all include about 1300 learner drivers at three stages of learning to drive and approximately 200 additional drivers who recently obtained their probationary licence.

Sample weights were introduced in order to ensure that for each survey year the results were representative of the learner population in terms of gender, region and age at permit acquisition.

Participants represent a cross-section of drivers in four approximate stages of learning to drive as indicated below.

Stage 1: 1 to 91 days (3 months) after obtaining a learner permit.

Stage 2: 92 to 212 days (7 months) after obtaining a learner permit.

Stage 3: 213 to 1461 days (4 years) after obtaining a learner permit.

Final Stage: the weeks spent in preparation for the licence test immediately before successful probationary licence acquisition (generally three to four weeks).

The sample of learner permit holders in each survey year was further stratified according to stage of the learner permit, gender, region of Victoria (Melbourne Metropolitan, Provincial Centres and the Rest of Victoria) and the age at which the driver first obtained a learner permit. Learner permit holders over the age of 70 and those who had held a permit for more than four years were excluded. Weighting factors were applied to each of the strata in order to ensure that the results were representative of the Victorian population of learner drivers at the time of each survey.

When considering unweighted data the 2014 learner permit holder survey participants were mostly aged 16 to 18 at interview (27% aged 16, 23% aged 17, 18% aged 18 and 32% aged 19 and above). There were 669 females and 663 males. These learners were younger if they resided in the Rest of Victoria (average age 18.8, versus 19.4 for Metropolitan Melbourne and 19.2 for Provincial Centres). The newly-licensed survey participants were mostly aged 18 and 19 (56% and 13% respectively), including 105 females and 106 males. Again those residing in the Rest of Victoria were younger (average age 19.2), compared with Metropolitan Melbourne (average age 21.7) and Provincial Centres (average age 19.6).

Learner survey respondents were asked about the amount of supervised practice they had completed in the last week and the amount of time they had spent in professional lessons in the last four weeks. Newly-licensed survey respondents were asked about the amount of supervised practice they had completed in the last week before passing the Drive Test and the amount of time they had spent in professional lessons in the last four weeks before they got their licence. Responses to these questions were aggregated to provide an estimate of the average total driving experience accumulated while holding a learner permit by that year's cohort of learner and newly-licensed drivers. Other questions were asked of respondents such as the number of crashes they had whilst on a learner permit, how long they held their learner permit and whether they participated in novice driver programs such as Keys Please. The questionnaire has been published in the 2007 Learner Monitor report (Pyta & Catchpole, 2007), but has been updated since that time (Meyer et al. 2014a).

Total supervised practice time in the previous week and total professional lesson time for the past four weeks is recorded for each participant, from which a total weekly driving time is calculated. This information is used in combination with the average time spent in each learning to drive stage (described above), to estimate the average total driving experience accumulated while holding a learner permit by that year's cohort of learner and newly-licensed drivers. These data have been used to determine if there are any significant trends in regard to the behaviour of learner drivers, especially in respect of gender, age at learner permit acquisition and region.

Data analysis

Three statistical methods were used for significance testing of the incidence of (1) professional lessons in the last four weeks, (2) supervised practice and (3) driving experience (professional lessons and supervised practice) in the last week for each of the learning to drive stages described above. Due to the large number of tests performed, only p-values below 0.01 were generally regarded as statistically significant, however, for the comparisons between years only p-values below 0.005 were regarded as significant. Table 1 describes the three statistical methods used. Together these analyses allow the monitoring of learner driver preparation over the last 15 years (9 surveys) in terms of progress in:

a. achieving the target of 120 hours of practice over the entire permit period
b. increasing weekly driving practice, both the likelihood of such practice in every week and the average practice time in those weeks where there is some practice.

Table 1. Data analysis methods used

Variables under analysis	**Statistical method**	**Description of statistical method**
The likelihood of professional lessons in the last four weeks, the likelihood of supervised practice and the likelihood of either of these in the last week	Binary Logistic Regression	The proportion of participants in each stage reporting at least one professional lesson in the last four weeks, at least one supervised practice session in the last week and at least some driving experience in the last week were considered in three separate analyses Region, gender and age at learner permit acquisition were controlled while testing for differences between the survey years Odds ratios were calculated using 1999 as the reference year
The mean time spent in professional lessons in the last four weeks and the mean time spent in supervised practice and/or professional lessons in the last week, considering only learner drivers with non-zero practice times. A log transformation was applied to these times allowing the assumption of normal distributions in this analysis	General Linear Model analyses	For each of the four stages, the effect of year was tested for non-zero practice times for weekly professional lessons, supervised practice and total driving times, while controlling for region, gender and age at learner permit acquisition. Mean (log transformed) practice times were analysed Comparisons with 1999 were conducted for each survey year and tests were performed for linear trends over the years
Total practice times for professional lessons and supervised practice during the entire learner permit period Total practice times considered both the likelihood of practice and the average time spent practising in each stage by considering average times which included zero times for learner drivers who reported no practice	Z-Tests	Z-tests were used to account for the changes in total practice times during the entire learner permit period, which also considered any trends that have emerged since 1999, and changes that have occurred since the start of the GLS by also making comparisons with 2005 (nearest valid comparison year close to the introduction of the new GLS for comparison)

Results

Likelihood that a learner driver had a professional lesson in the last four weeks, supervised practice in the last week and driving experience (both professional lessons and supervised practice) in the last week

Binary Logistic Regression was used to determine the statistical significance of year, gender, region and age at learner permit, with odds ratios (OR) above one indicating an increased likelihood of practice and odds ratios below one indicating a decreased likelihood of practice.

The following results were found to be statistically significant (p<.01) for the likelihood that a learner driver had a professional lesson in the last four weeks, supervised practice in the last week and driving experience (both lessons and practice) in the last week:

- There were higher odds for at least one professional lesson for learners in Metropolitan Melbourne than in rural areas in Stage 2 (OR=2.22) and Stage 3 (OR=1.61), for females than males in Stage 2 (OR=1.57) and Stage 3 (OR=1.43), for learner drivers who were 18+ rather than 16 when acquiring their permit in Stage 1(OR=2.77), Stage 2 (OR=3.03) and Stage 3 (OR=1.74) and for learner drivers who were 17 rather than 16 when acquiring their permit in Stage 2 (OR=2.41) and Stage 3 (OR=1.72).
- There were higher odds (OR=2.38) for at least one professional lesson in the Final Stage for drivers who were aged 16 years rather than 18+ at learner permit acquisition.
- There were higher odds of supervised practice among learners in rural than metro areas in Stage 1 (OR=1.71), Stage 2 (OR=1.75), Stage 3 (OR=1.49) and the Final Stage (OR=1.72), among males than females in Stage 2 (OR=1.67) and Stage 3 (OR=1.30), among drivers aged 16 than drivers aged 17 at learner permit acquisition at Stage 2 (OR=1.52) and Stage 3 (OR=2.44), and among drivers aged 16 than drivers aged 18+ at learner permit acquisition at Stage 1 (OR=1.96), Stage 2 (OR=2.38), Stage 3 (OR=4.35) and the Final Stage (OR=2.38).
- On average, in any year since 1999, the odds for:
  - professional lessons in the last four weeks in Stage 3 declined by 5.3% per annum for females aged 17 at learner permit acquisition (Wald=7.41, df=1, p=.006) and by 6.5% per annum for females aged 16 at learner permit acquisition (Wald=25.52, df=1, p<.001)
  - supervised practice in the last week for learners in Stage 3 increased by 11.5% per annum in the case of females aged 17 at learner permit acquisition (Wald=35.97, df=1, p<.001) and by 2.9% per annum in the case of females aged 16 at learner permit acquisition since 1999 (Wald=8.41, df=1, p=.004)
  - any supervised practice in the last week for learners in Stage 3 increased by 5.5% per annum in the case of females aged 17 at learner permit acquisition (Wald=10.12, df=1, p=.001)
  - professional lessons in the last four weeks for learners in Stage 3 declined by 4.8% per annum for females in Metropolitan Melbourne (Wald=24.38, df=1, p<.001)
  - supervised practice in the last week in for learners Stage 3 increased by 5.0% per annum in the case of females in Metropolitan Melbourne (Wald=30.44, df=1, p<.001)

Time learner drivers spent in professional lessons in the last four weeks, supervised practice in the last week and driving experience (both professional lessons and supervised practice) in the last week

Region, gender and age at learner permit acquisition had a strong impact on the (non-zero) time that a learner driver spent in professional lessons in the last four weeks, supervised practice in the last week and driving experience in the last week. The following results, using Generalised Linear Modelling with a log transformation for the times, were statistically significant (p<.01):

- Less time spent in professional lessons for those aged 16 at learner permit acquisition rather than 17+ in Stage 2 (14 minutes per week shorter on average: F(1,187)=12.4, p<.001), Stage 3

(5 minutes per week shorter on average: F(1,1263)=45.52, p<.001) and the Final Stage (6 minutes per week shorter on average: F(1,1684)=10.43, p=.001).

- More time spent in professional lessons for those living in Metropolitan Melbourne in Stage 3 (five minutes higher than in Rural Victoria on average: F(1,1264)=7.39, p=.007) and the Final Stage (twelve minutes per week higher than in Rural Victoria on average: F(1,1684)=44.49, p<.001).
- More time spent in professional lessons for females in the Final Stage (45 minutes for males and 51 minutes for females on average: F(1,1684)=13.63, p<.001).
- Lower supervised practice times in Stage 2 for females (82 minutes versus males at 103 minutes: F(1,714)=10.87, p=.001), Metropolitan Melbourne participants (80 minutes versus 105 minutes in Rural Victoria: F(1,714)=8.975, p=.003) and those who obtain their permit at age 16 years (77 minutes per week compared to those who were older at the age of learner permit acquisition of 108 minutes: F(1,714)=23.99, p<.001).
- An average increase from 1999 to 2014 in supervised practice times in Stage 3 of 2.8% and 2.7% per annum for females aged 16 and 17+ at learner permit acquisition (t(1223)=5.12, p<.001; t(539)=2.664, p=.008). Also an average increase of 3.0% and 3.8% per annum for overall driving experience for females aged 16 and 17+ at learner permit acquisition (t(1311)=5.452, p<.001; t(749)=4.508, p<.001).
- An average increase from 1999 to 2014 in supervised practice in the Final Stage of 4.1% per annum for females aged 17+ at learner permit acquisition (t(243)=2.72, p=.007).
- An average increase from 1999 to 2014 in supervised practice times in the Final Stage of 3.5% per annum for males in Metropolitan Melbourne (t(443)=3.962, p<.001). Also an average increase of 2.0% per annum for overall driving experience (t(607)=2.60, p=.009).
- An average increase from 1999 to 2014 in for supervised practice in the Final Stage of 2.9% per annum for females in Metropolitan Melbourne (t(412)=3.425, p=.001).

High-level 2014 survey findings

The 2014 Learner Monitor survey indicated that the total amount of driving experience on a learner permit was 118.6 hours for that year. This is in contrast to the average of 82.9 hours in 1999. The 2014 Learner Monitor found females increased their total hours in supervised practice from 61.3 hours in 1999 to 101.6 hours in 2014 (Meyer, Cunningham & Rajendran, 2014a).

Practice hours (supervised practice and professional lessons combined) across the learner permit period (all stages)

Total practice hours across the surveys

Overall when considering all ages, there was a steady increase in practice hours across the learner permit period since 1999 (83 hours), with a slight decrease in 2008 after the GLS changes were introduced. There was on average a statistically significant increase of 4.6 hours per survey (2.5 hours per annum) in estimated total hours of driving during the entire permit period (estimated using simple linear regression analysis, t(7)=11.75, p<.001). Importantly the 2014 average is only just below the 120 hours mandated in 2007 (119.1 hours which does not match the figure of 118.6 hours total practice hours from the 2014 Learner Monitor survey mentioned earlier, because the comparison across years shown in Figure 1 requires the use of a consistently interpolated correction factor). The Z-test results found that in comparison with 1999, a statistically significant improvement occurred from 2005 to 2014 (p<.005). However, in comparison with 2005, there were no statistically significant improvements over the survey years although significance was nearly achieved for 2014 (Z=2.261, p=.006).

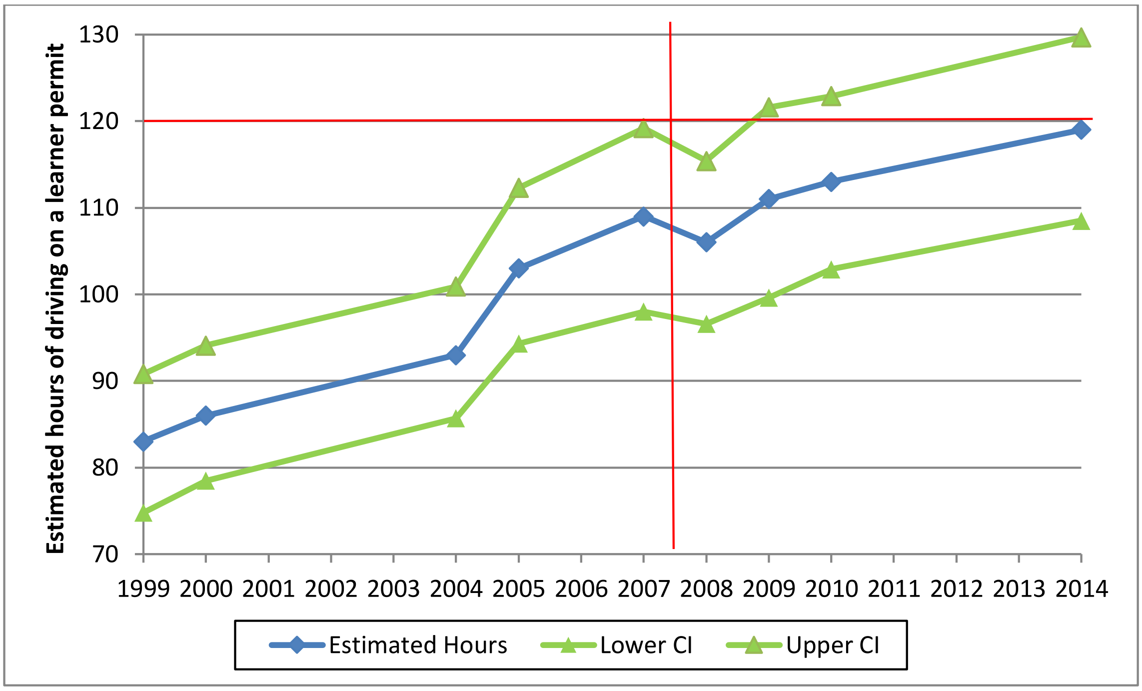

Figure 1. Estimated total practice hours (all groups) with 95% confidence intervals (note: vertical line denotes introduction of new Victorian GLS and horizontal line denotes the 120 hour practice requirement with linear interpolation between surveys)

Average increases in hours across the surveys by age at learner permit acquisition

The average increase of 10.1 hours per survey (5.3 hours per annum) since 1999 for all learner drivers who acquired a learner permit at the age of 17, starting from a base permit practice time of 46 hours in 1999, was statistically significant ($t(7)=8.625$, $p<.001$). However, the average annual increase in total practice times since 1999 was not statistically significant for those who acquired a permit at the age of 18 or older despite a 40% increase in average learner permit duration. For these learner drivers the improvement since 1999 (2.9 hours per survey, 2.2 hours per annum) was not large enough to provide a statistically significant trend ($t(7)=2.408$, $p=.047$). There has only been a 14% increase in the average permit duration for those who acquired a permit at age 16 so the average annual increase in total driving practice since 1999 (2.5 hours per survey, 1.2 hours per annum) was also found to be not statistically significant ($t(7)=1.721$, $p=.030$).

120 hours target and comparisons to 1999 and 2005

Those who were 16 at permit acquisition achieved significantly more than the target of 120 hours driving practice in 2014 (137 hours; $Z=2.626$, $p=.004$). The average total time for those who acquired their permit at the age of 17 was 127 hours, which was not significantly higher than the 120 hour target ($Z=.371$, $p=.645$). The total time for those aged 18 or older at learner permit acquisition was only 88 hours, significantly lower than the target of 120 hours ($Z=3.158$, $p=.001$).

Table 2 shows the result of annual comparisons (Z-test scores) to determine whether changes since 1999 and 2005 were statistically significant for each year by age at learner permit acquisition. For drivers aged 17 at learner permit acquisition there has been a strong improvement, which is especially noticeable after the GLS changes in 2007. For those who acquired a permit at age 16 there was an improvement in 2005 and also in 2014. There was no improvement for those aged 18 at permit acquisition.

Table 2. Z-Test Scores for total practice hours comparisons across survey years by age (p<.005)*

Survey year	Comparison with 1999			Comparison with 2005		
	Age at learner permit acquisition					
	16	17	18 +	16	17	18 +
1999	0.000	0.000	0.000			
2000	1.514	1.504	-1.734			
2004	1.850	2.913*	-1.621			
2005	2.609*	2.326*	0.532	0.000	0.000	0.000
2007	2.192	3.563*	0.984	-0.378	1.027	0.531
2008	1.893	4.286*	0.047	-0.750	2.523*	-0.509
2009	1.335	4.396*	0.732	-1.286	2.806*	0.251
2010	1.984	4.295*	1.775	-0.696	2.577*	1.231
2014	3.279*	4.143*	0.925	0.582	2.954*	0.363

* Statistical significance at p<.005 to allow for increased intensity of testing

120 hours target and gender/location comparisons

Z-tests were also used to compare mean total practice times with the target level of 120 hours. It was found that in 2014 females significantly exceeded the 120 hour target, with an estimated mean practice time of 152 hours in Metropolitan Melbourne and 126 hours in Rural Victoria. For females living in Metropolitan Melbourne and in Rural Victoria, the average increase per year was 6.9 hours and 7.1 hours per survey respectively, 3.8 hours per annum in both groups, starting from a base permit practice time of 86 hours and 78 hours in 1999. These trends were statistically significant in both cases ($t(7)=4.212$, $p=.004$; $t(7)=8.326$, $p<.001$).

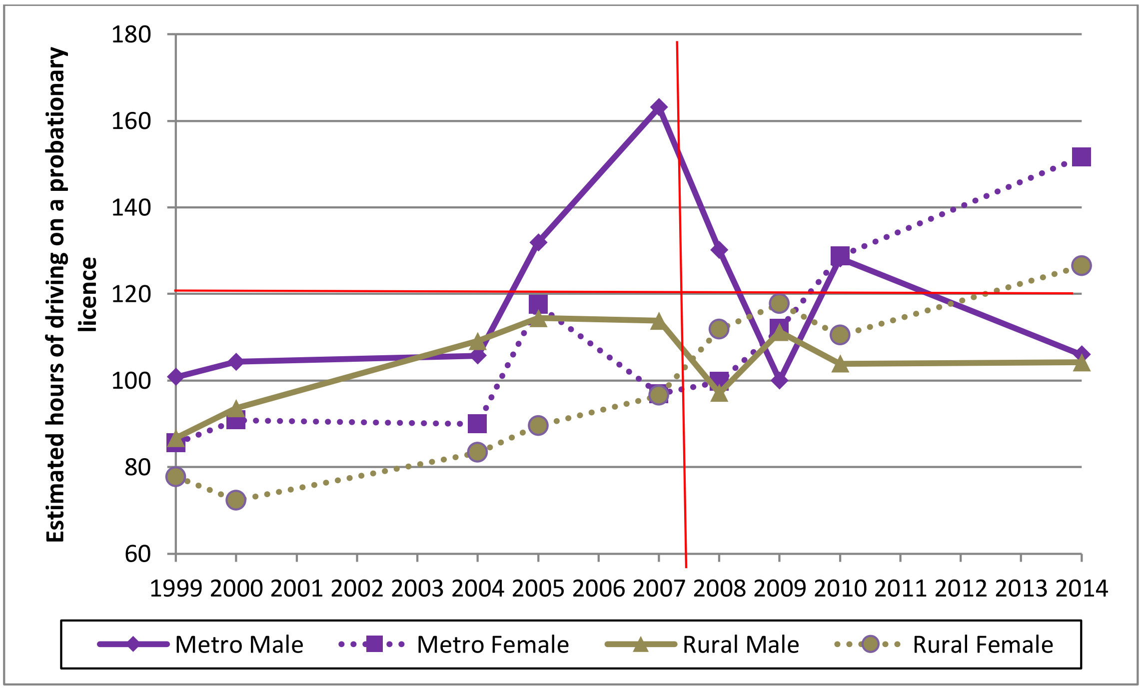

Figure 2. Estimated total practice hours by gender and region
(note: vertical line denotes introduction of new Victorian GLS and horizontal line denotes the 120 hour practice requirement with linear interpolation between survey years)

However, for males the average annual increase in total practice times since 1999 was not statistically significant despite close to a 30% increase in average permit duration. With respect to males in Metropolitan Melbourne the increase in practice was on average only 0.8 hours per survey (0.9 hours per annum), starting from a base permit practice time of 101 hours in 1999. Males in Rural Victoria achieved an increase of 2.4 hours per survey (1.0 hours per annum) on average, starting from a base practice time of 87 hours in 1999. Clearly males in Metropolitan Melbourne started from a relatively high base in 1999, but their low level of improvement since then indicates that, like Rural Victorian males, their 2014 level of practice was relatively low compared to the females (Figure 2).

Discussion and Implications

The aim of this research was to determine if learners, including subgroups of learners, were reaching the 120 hours practice target and to indirectly evaluate the effect of the Victorian GLS in terms of learners achieving practice. The findings suggest the GLS has been a success for some learner subgroups, but not others. It was found that those who are 16 at learner permit acquisition exceeded the 120 hour expectation with an average of 137 hours. It is hypothesised that these learners wish to obtain their licence at the earliest possible age, 18, and are dedicated to achieving the target. Those aged 17 at learner permit acquisition, who obtained 127 hours, also appear to have this goal.

Learners who acquired their permits at age 18 or more were significantly below the 120 hour target in 2014 with an average time of only 88 hours. These learner drivers improved very little since 1999 (only 2.2 hours per annum), suggesting that the GLS changes had little if any impact on this subgroup of learner drivers. One reason for this could be the recent trend in highly motorised countries of obtaining a licence at a later age. For instance, Delbosc and Currie (2013) found decreasing licensing trends in 9 of 14 countries, with a one percent per annum decline among 18 to 23 year olds in Victoria. The authors indicated the decline to be related to life stage, such as increasing participation in education, decreasing full-time employment rates and delaying marriage and children. The authors considered that the GLS may act as a barrier to young people obtaining a licence, but considered the impact to be small, especially as licensing rates began to drop prior to the GLS in some countries.

The comparatively low number of practice hours obtained by 18+ year olds could occur for life stage reasons, and possibly avoidance of the requirements of the GLS. However, respondents to the 2014 Learner Monitor survey indicated they had been too busy to learn to drive any sooner and/or they had not needed to drive when asked if they expected to delay licensing until the age of 21 or older. Regardless of the reasons why learners delay licensing, there is a road safety benefit occurring from the protection effect of increased age at licensing (greater maturation (Senserrick & Williams, 2014)).

Females, those residing in Melbourne, and those who obtained their learner permit at the age of 17 or older were identified in the first 1999 Learner Monitor report as averaging fewer hours of practice than other subgroups. The increases observed among these subgroups, particularly following the introduction of the GLS, indicate they are now achieving the 120 hour target. Some of this may be due to extending the minimum period for which the learner permit must be held from 6 to 12 months (effect of the GLS) which provides more time for practice. The average practice time per week has also increased for these two groups of learner drivers, which may be motivated by the GLS 120 hour requirement.

However, male learners are a problem subgroup with no statistically significant average annual improvement since 1999, and Metropolitan Melbourne males' practice since the introduction of the GLS has reduced, which could be a correction of overall trends (there was a spike in their practice before the GLS). In addition, males are not meeting the 120 hour target, suggesting that male-targeted interventions are now required. Those 18 years and older will also require intervention in addition to males in order to benefit from a reduced crash risk at licensing. Victoria's road safety partners will need to work together on relevant programs for these subgroups. It may also be worthwhile examining differences between learners intending to get a licence before or after turning 21, as they may still plan to obtain 120 hours of supervised practice.

The overall results of the Learner Monitor from 1999 to 2014 are encouraging, with an increase in practice hours from 83 hours to 119 for all learners. The amount of practice Victorian learners are achieving is commendable as this will decrease their crash risk once licensed. Victoria and New South Wales (NSW) mandate the highest number of hours (120), followed by Queensland (100), with other states mandating less or no practice hours. On this basis it might be expected that Victorian learners achieve the highest levels of practice in Australia. Learners achieving high practice hours in Victoria may also be linked to the 18 year old licensing age (all other states have a lower licensing age) and the fact that 16 year olds hold the learner permit for at least two years (Senserrick & Williams, 2014).

Conclusion

Over the past 20 years road safety partners across Victoria have worked together to increase community understanding and acceptance of the protective benefits accruing from 120 hours of supervised practice. VicRoads, the Transport Accident Commission (TAC) and Community Road Safety Councils all introduced programs, including publicity, to promote increased driving practice for learner drivers and their parents/supervising drivers in Victoria. Bringing the community along on the journey and gaining their acceptance for this road safety countermeasure has been an important factor in achieving the acceptance of the legislated 120 hour requirement. The Learner Monitor surveys demonstrate that these combined efforts are associated with an increase in the amount of time spent in supervised practice, especially amongst learners from the original 'most at risk' subgroups. However, there is still work to be done with those aged 18 or more at learner permit acquisition and males in general. This research will form part of Victoria's overall evaluation of its GLS effectiveness, which is a project still in progress.

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Please note: abstract *only* available - check website for the full version of this paper

Effectiveness of an on-road motorcycle rider coaching program: a randomised control trial

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Soufiane Boufous and Liz de Rome

Abstract

There is no compelling evidence to date showing effectiveness of training programs for newly licensed motorcycle riders. The VicRide program is a low risk, half-day, on-road motorcycle coaching program aimed at reducing risk of crash in new riders. This study evaluated the effectiveness of the program.

Methods

A randomised trial was conducted across the state of Victoria, Australia between 2010-2014. Consenting riders were randomly allocated into program or control groups. Those in the program group were invited to undertake the coached ride within 6 weeks of the baseline interview; the control group were offered the program at the end of the trial. Both the program and control groups completed surveys by telephone at 3 time-points: baseline (pre-randomisation), 3 months and 12 months. Outcomes include crash involvement (police and self-reported), near misses, offences, riding exposure, attitudes and behaviours. Differences in outcomes were compared using various regression analyses, in intention-to-treat analyses.

Results

Of 2399 consenting participants, 81% were male, the average age was 35 years, and average reported riding was 163.9 km, or 4.1 hours, per week. Sports bikes were the most commonly reported (39%) followed by standard bikes (25%), and cruisers (21%). Approximately 60% of those allocated to the program group completed the coached ride; the response rate for surveys was 88.7% at 3 months, and 87.6% at 12 months. Main outcome results will be presented.

Conclusions

The results of this large scale trial will provide strong evidence for effectiveness of motorcycle coaching programs, and will have significant policy implications.

Factors involved in cyclist fatality crashes: a systematic literature review

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Abstract

In this study, a systematic review was undertaken to identify the factors that contribute to cyclist fatality crashes. The review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses for Protocols 2015 (PRISMA-P) and examined original, peer-reviewed and non-peer-reviewed publications indexed in 10 databases from their inception to November 2014. Contributing factors were identified and analysed using the four pillars of the Safe System approach: safe people, safe roads and roadsides, safe speeds and safe vehicles. In total, 71 papers were included and 52 contributing factors were identified. The review highlights that many system-wide factors that contribute to cyclist fatality crashes have been identified in the literature. Specifically, the majority of factors related to the road user (61.5%), followed by the road and roadside (19.2%), vehicle characteristics (13.5%) and speed (5.8%). Notably, the majority of crashes examined in the literature involve a motor vehicle, it is not known how these crash factors translate to non-vehicle or off-road cyclist fatality crashes. Despite the relatively high involvement of behavioural factors as contributors, the Safe System framework supports a multi-factorial approach to countermeasure development to prevent future cyclist fatality crashes.

1. Introduction

In Australia, in the decade from 2003-2012, an average of approximately 32 cyclists died annually (Bureau of Infrastructure 2013). In 2013, cyclist deaths peaked with 50 fatalities (Bureau of Infrastructure 2014). Every transport death impacts the family and friends of the deceased as well as people involved in or who witnessed the crash. There is also a substantial economic cost of human loss; cyclist deaths in 2013 and 2014 alone have been estimated to have incurred an economic cost of A$228 million (Bureau of Infrastructure 2006). The level of cyclist trauma is a significant concern as Australia has strong policy support for increased cycling participation. At a national level, the overarching vision of the current National Cycling Strategy is to double cycling participation by 2016 (Austroads 2010). The challenge is how to achieve greater cycling participation without simultaneously increasing cyclist road trauma.

From a theoretical perspective, road safety in Australia is underpinned by the Safe System approach. This conceptual framework takes into consideration system-wide factors categorised into four quadrants: safe people, safe roads and roadsides, safe vehicles and safe speed. However, this approach has not been widely applied to the study of cyclists (Johnson 2011). Typically the analysis of cyclist crashes focuses on the behaviour of the road users involved (safe people), with less consideration given to the role of broad system factors (safe roads and roadsides, safe vehicles and safe speed). This literature review has not identified a systematic analysis of the system-wide factors in cyclist fatality crashes. However, an in-depth understanding of all potential contributing factors is critical for informing the design and development of countermeasures to prevent cyclist fatalities.

To address these gaps, the aim of this study was to conduct a systematic review to identify all factors that contributed to cyclist fatality crashes reported in the published literature and to consider those factors within the Safe System approach.

2. Method

The review was conducted in accordance with the Preferred Reporting Items for Systematic reviews and Meta-Analyses for Protocols (PRISMA-P) statement (Moher et al. 2015). The following scientific databases for the disciplines of transport and injury prevention were searched from their inception to November 2014: Cochrane Database of Systematic Review; Compendex; EBSCO; EMBASE; Informit; OVID – Medline; OVID – Transport; Scopus; TRID; and Web of Science. Three research concepts were derived by the authors: “bicycle/cyclist”; “death”; and “crash” and key terms associated with these concepts were developed (Table 1). These terms were grouped using the Boolean operators ‘and’/’or’. The full search with the final research concepts and key terms was conducted on 11 November 2014 (MJ).

Table 1. Master list of research concepts and key terms

Concept 1 – Bicycle/Cyclist	Concept 2 – Death	Concept 3 – Crash
bicycl*	mortal*	crash*
bik*	death*	accident*
cyclist*	fatal*	collid*
cycling		collision*

2.1 Data: eligibility criteria, extraction and analysis

The eligibility criteria included: English language, results disaggregated by outcome (fatal or other injury levels), road user and at least one contributing crash factor. Studies of aggregated data were excluded because of insufficient cyclist fatality crash detail. Factors were grouped into the four Safe System approach pillars: safer people, safer road and roadsides, safer speeds and safer vehicles. Non-peer-reviewed literature was included as it provided broader, more detailed descriptions of the crash circumstances than peer-reviewed literature alone. Publications were categorised into three groups: white (peer-reviewed journal articles); grey (reports and documents generated from official data but not peer-reviewed) and dirty (popular media).

Two authors (MJ, CM) reviewed all titles and abstracts to identify publications for inclusion and disputed publications were independently adjudicated (LB). The authors reviewed the publications and extracted the following data: authors; year; title; study aim; article type (white, grey, dirty); country, state/province, county; years of data collection; research design; data analysis; comparison group; outcome (fatal, serious injury, minor injury); crash location (all, on road, off road); age; sex; total deaths reported; crash types; contributing factors people; contributing factors vehicle; contributing factors speed; contributing factors roads and roadsides; risk factors other; summary of main findings; articles identified from bibliographic review, and; data analysis method used.

Extracted data analysed using IBM SPSS Statistics 22. A descriptive statistical analysis was conducted to report: the publication characteristics; presence and contribution of factors outlined in the Safe System approach (people, roads and roadsides, vehicle and speed). Statistically significant differences between categorical variables were calculated using Pearson Chi-Square tests.

3. Results

3.1 Publication selection

The combined searches yielded 11,874 publications, which was reduced to 3,955 after duplicates were removed. Following a review of the title and abstract, this was reduced further to 186 publications. A full text review, including a manual bibliographic review, identified 71 articles eligible for inclusion (Figure 1). See Table 2 for details of included publications. The 71 publications included in the review were published between 1969 and 2015 primarily in developed countries. This comprised publications from the United States of America (n=23), the United Kingdom (n=19), Australia (n=7), 3 publications from each of Finland and France, 2 publications from each of Canada, China, Denmark, Germany and Sweden, and 1 publication from each of Austria, Czech Republic, Italy, Japan, the Netherlands and Norway.

The majority of publications were peer-reviewed journal articles (white literature) (n=32), 20 were non-peer-reviewed newspaper articles (dirty literature) and 19 were non-peer-reviewed reports (grey literature). Amongst the 32 peer-reviewed journal articles, retrospective study designs comprised used included: 25 case series studies, 5 case reports and 2 case-control studies. The white literature was largely based on police (30.3%) and coronial data (27.2%), the grey literature also used police reports (31.5%) and FARS (26.3%) the US Fatality Analysis Reporting System. All FARS reported crashes occurred on a public roadway and involved a crash with a motor vehicle that resulted in the fatality of a motor vehicle occupant or non-occupant within 30 days of the crash(Health Indicators Warehouse 2010). Of the dirty literature, the majority was based on media reports (55.0%) and court proceedings/findings (25.0%). Other data sources used included GIDAS, the German In-Depth Accident Study(Orsi et al. 2013) and the Queensland Child Death Case Register(Fraser et al. 2012) which reviews the deaths of children aged under 18 years by a panel of experts. The majority of publications (61, 85.9%) examined on-road crashes only, 9.8 percent (n=7) examined both on-road and off-road, 1 study examined off-road crashes and 2 studies did not specify the crash location.

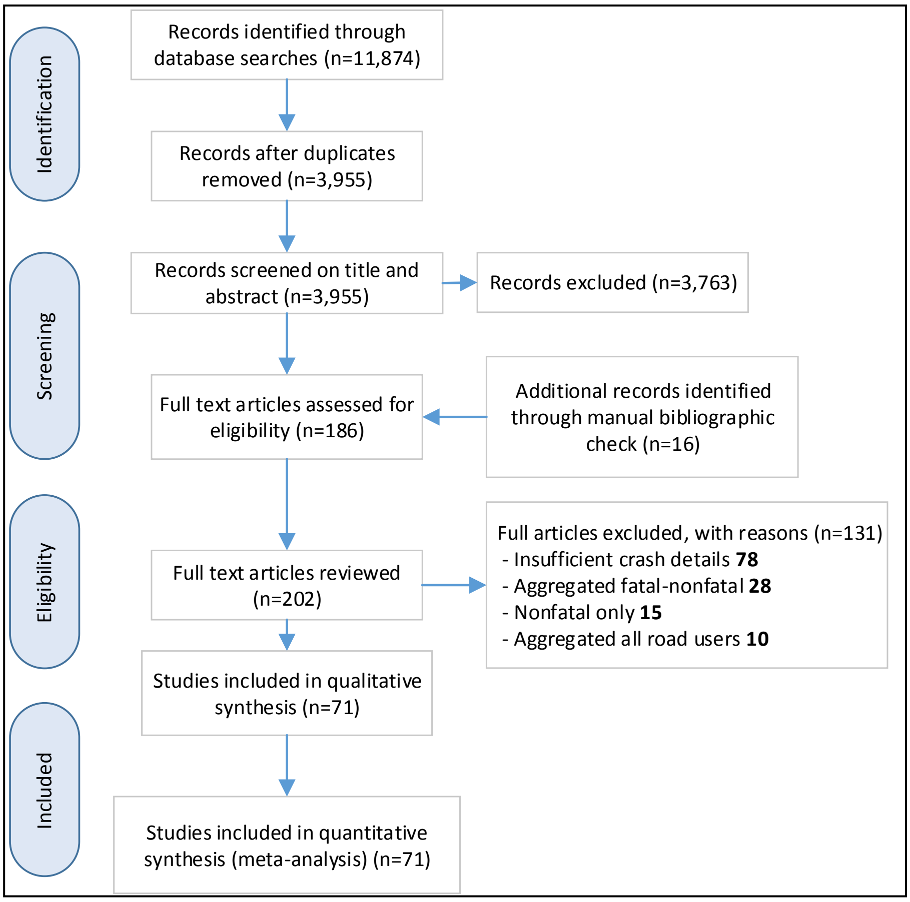

Figure 1. Publication identification, screening, eligibility and inclusion

3.3 Publication findings

In total, 52 discrete factors were identified in the literature as being involved in cyclist fatality crashes (see Table 3). The majority of factors related to the behaviour of the cyclist and the counterpart involved in the crash (safe people: 32 factors; 61.5%), followed by the road and/or roadside (10 factors; 19.2% each), the vehicle (7 factors; 13.5% each) and three factors (5.8%) related to excessive speed by the road user or specific mention of a high posted speed limit contributing to the crash. Two contributing factors outside the Safe System approach were identified as contributing to cyclist fatality crashes; these were categorised as Other (weather, traffic volume). The majority of publications reported the involved factors without any statistical analysis (61.0%), a third used descriptive statistics (36.2%) and the remainder conducted statistical analysis (2.8%).

3.3.1 Safe System factors – Safe People

The majority of factors identified in the literature were within the safe people category and related to behavioural factors of the cyclist and/or the counterpart(s) (61.5%).

Personal protective equipment: Helmets were the primary focus, particularly use/non-use (53.5%) with widespread support for helmet use (Got 1993, Sjöegren et al. 1993, Bajanowski et al. 1994, Bernhoft 1994, Maki et al. 2003, Kelkka and Toivonen 2011, Clarke 2014) associated with a decreased probability of a fatal outcome (Öström et al. 1993, Kim et al. 2007, Fredriksson et al. 2012). High visibility clothing was identified as important to increase cyclists' conspicuity and non-use was considered contributive in low light/dark crashes (Attewell and Dowse 1992, Cycling Weekly 2008, Daily Mail 2010).

Impairment: Substance misuse was the most frequently identified cause of impairment. Excessive alcohol consumption and drug used was noted by over half the publications (57.7%). There was a consensus about a relationship between intoxication and cyclist fatality (Cooke et al. 1993, Nicaj et al. 2009, Fraser et al. 2012) with a greater probability of fatality, particularly when the driver was intoxicated (Olkkonen 1993, Kim et al. 2007). Other impairments included health- (Klintschar et al. 2003, Akhtar et al. 2010) and age-related impairment (Olkkonen 1993, Bajanowski et al. 1994, Bernhoft 1994), and temporary impairment states (e.g. distraction, inattention (Bicycle Retailer & Industry News 2008, Keigan et al. 2009, Akhtar et al. 2010, Clarke 2014) fatigue (Bingham 2007, Akhtar et al. 2010)).

Responsibility or fault: Crash responsibility or who was at fault was frequently reported and typically determined as the person who violated traffic rules to establish legal liability (Noordzij 1976, Cross and Fisher 1977, Olkkonen 1993). On average, cyclists were at fault in 58.6% of fatality crashes (range: 37.3% (Olkkonen 1993) to 75% (Bajanowski et al. 1994)) with higher proportions reported in age-specific cyclist groups (children under 14 years: 100% (Dupont 1996); elderly: 83% (Olkkonen 1993)).

Error: Failure to see was the most commonly reported error, typically by drivers (Hoque 1990, Keigan et al. 2009, Valentine and Tillman 2010, Kelkka and Toivonen 2011, Lydall 2014) attributed to factors including: drivers' low expectancy of cyclists (Akhtar et al. 2010), driver cognitive load (Akhtar et al. 2010), driver inattention (daSilva et al. 2002, Akhtar et al. 2010), glare (ATSB 2006), cyclists in drivers' blind spot (McCarthy and Gilbert 1996, Akhtar et al. 2010), cyclists' lack of conspicuity (e.g. lack of bike lights)(Cycling Weekly 2008, Akhtar et al. 2010). Impairment due to substance misuse, including alcohol, by drivers also contribute to a failure to see (Rowe et al. 1995, ATSB 2006). Other errors included cyclist or driver misjudgement (Sjöegren et al. 1993, Bernhoft 1994, daSilva et al. 2002, Akhtar et al. 2010); loss of control (Got 1993, Ciferri 2005, Akhtar et al. 2010); unexpected behaviour (Öström et al. 1993, Spence et al. 1993, Komanoff and Smith 2000, Hutchinson and Lindsay 2010); visual obstruction (Klintschar et al. 2003, Nicaj et al. 2009, Hutchinson and Lindsay 2010); failed evasive manoeuvre (Cooke et al. 1993, Arenson 1997) and expectation (i.e. driver expected cyclist to yield)(Akhtar et al. 2010).

Violation: Behaviours that actively contributed to the crash event, as opposed to passive errors, were grouped as violations. Failure to yield was the most frequently identified violation by both cyclists (Got 1993, Sjöegren et al. 1993, Bernhoft 1994, US Department of Transportation 1994, McCarthy and Gilbert 1996, daSilva et al. 2002, Akhtar et al. 2010, Bíl et al. 2010, Kelkka and Toivonen 2011, Clarke 2014) and drivers (Bajanowski et al. 1994, Liu et al. 1995, McCarthy and Gilbert 1996, daSilva et al. 2002, Akhtar et al. 2010, Bíl et al. 2010, Hutchinson and Lindsay 2010, Clarke 2014). Cyclist violation was typically failure to stop at traffic signals (e.g. stop sign, red light)(Spence et al. 1993, Liu et al. 1995, Keigan et al. 2009, Valentine and Tillman 2010, Lydall 2014). Driver violation included overtaking cyclists too closely (Got 1993, Bernhoft 1994, McCarthy and Gilbert 1996, Clarke 2014), infringement of road rules, infringement at red lights, causing a hazard by opening a vehicle door (Liu et al. 1995, Arenson 1997, Komanoff and Smith 2000).

Habitual driving behaviour, including stretching the rules (e.g. previous speeding infringements)(Valentine and Tillman 2010), distraction (e.g. mobile phone use).

Other factors: Knowledge and experience, or lack thereof, was identified as contributing behavioural factors. Cyclists' lack of knowledge or indifference to road rules was identified (Cross and Fisher 1977, Akhtar et al. 2010, Kelkka and Toivonen 2011, Fraser et al. 2012) whereas lack of experience was identified for both cyclists (Cross and Fisher 1977, Liu et al. 1995, Webster 2006, Keigan et al. 2009, Fraser et al. 2012) and drivers (Mooar and Thomas-Lester 1997, Akhtar et al. 2010). Inadequate driving training was also identified (Akhtar et al. 2010).

Table 2. Details of publications on cyclist fatality crashes

Study	Type	Country	Method	Sample description			Safe System				
			Study design	Age	Sex	Total deaths	People	Speed	Vehicle	Road	Other
(Abt 1995)	D	France	N	A	M	9	+	+	-	+	-
(Ackery 2012)	W	USA	R, CC	All	All	711	+	-	+	-	-
(Akhtar et al. 2010)	G	Norway	R, CS	All	All	15	+	+	+	+	+
(Arenson 1997)	D	USA	N	A	F	1	+	-	+	-	-
(Attewell and Dowse 1992)	G	Australia	R, CS	All	All	86	+	+	+	+	-
(ATSB 2006)	G	Australia	R, CS	All	All	335	+	-	+	-	+
(Bajanowski et al. 1994)	W	Germany	R, CS	All	All	48	+	-	+	-	+
(Baker et al. 1993)	G	USA	R, CS	All	All	1984	+	-	-	-	-
(Bernhoft 1994)	W	Denmark	R, CS	A	All	89	+	+	-	-	-
(Bicycle Retailer & Industry News(2008)	D	USA	N	A	M	1	-	-	-	-	-
(Bíl et al. 2010)	W	Czech Republic	R, CS	All	All	968	+	+	-	+	-
(Bingham 2007)	D	UK	N	All	All	1	+	-	-	-	-
(Carpiet 2014)	D	USA	N	All	All	1	+	-	-	-	-
(Ciferri 2005)	D	Italy	N	A	M	1	+	-	-	-	-
(Clarke 2014)	G	USA	R, CS	A	All	633	+	-	-	-	-
(Cooke et al. 1993)	W	Australia	R, CS	All	All	64	+	-	-	-	-
(Cross and Fisher 1977)	G	USA	R, CS	All	All	166	+	+	+	+	+
(Cycling Weekly, 2008(2008)	D	UK	N	A	M	1	+	-	-	+	-
(Daily Mail, (2010)	D	UK	N	A	M	1	+	-	-	-	-
(daSilva et al. 2002)	G	USA	R, CS	All	All	760	+	+	+	+	+
(Dix and Bolesta 1988)	W	USA	R, CS	C	M	1	+	-	+	-	-
(Dupont 1996)	W	Denmark	R, CC	A	All	447	+	-	+	-	-
(Fife et al. 1983)	W	USA	R, CS	C	All	2	+	-	+	+	-
(Fraser et al. 2012)	W	Australia	R, CS	C	All	12	+	-	-	+	-
(Fredriksson et al. 2012)	W	Sweden	R, CS	All	All	48	+	-	+	-	-
(Gilbert and McCarthy 1994)	W	UK	R, CS	All	All	178	+	-	+	-	-
(Got)	G	France	R, CS	All	All	378	+	-	+	+	-
(Hawley et al. 1995)	W	USA	R, CS	All	All	36	+	-	-	-	-
(Hoque, 1990)	W	Australia	R, CS	All	All	122	+	-	+	+	-
(Hutchinson and Lindsay 2010)	G	Australia	R, CS	All	All	37	+	+	-	-	-
(IOM Today, (2008)	D	UK	N	C	M	1	+	-	+	-	-
(Keigan et al. 2009)	G	UK	R, CS	All	All	92	+	+	+	+	-
(Kelkka and Toivonen 2011)	G	Finland	R, CS	All	All	31	+	-	-	+	-
(Kim et al. 2007)	W	USA	R, CS	All	All	104	+	+	-	+	+
(Klintschar et al. 2003)	W	Austria	R, CStudy	C	M	1	+	-	-	-	-
(Komanoff and Smith 2000)	G	USA	R, CS	All	All	71	+	+	-	-	-
(Levy 2007)	D	UK	N	C	M	1	+	-	-	-	-
(Liu et al. 1995)	W	China	R, CS	All			+	+	-	+	+
(Lydall 2014)	D	UK	N	A	F	1	+	-	-	-	-
(Maki et al. 2003)	W	Japan	R, CS	A	-	9	+	-	+	-	-
(McCarthy and Gilbert 1996)	W	UK	R, CS	All	All	124	+	+	-	-	+
(Mooar and Thomas-Lester 1997)	D	USA	N	A	F	1	+	-	-	-	-
(Moore-Bridger 2009)	D	UK	N	A	F	1	+	-	+	-	-
(Moore-Bridger 2010)	D	UK	N	A	F	1	+	-	-	-	-
(Morgan 2014)	D	UK	N	A	M	1	+	-	-	+	-
(Morgan Andrei et al. 2010)	W	UK	R, CS	A	All	242	+	-	-	+	-
(New York Times,(2000)	D	USA	N	A	F	1	+	-	-	-	-
(Nicaj et al. 2009)	W	USA	R, CS	All	All	225	+	-	+	+	-
(Nie et al. 2015)	W	China	R, CS	A	M	67	-	+	+	-	-
(Nixon et al. 1987)	W	Australia	R, CS	C	All	46	+	-	-	-	-
(Noordzij 1976)	W	The Netherlands	R, CS	All	All	1382	-	-	+	+	+

Study	Type	Country	Method	Sample description			Safe System				
			Study design	Age	Sex	Total deaths	People	Speed	Vehicle	Road	Other
(Olkkonen 2002)	W	Finland	R, CS	All	All	23	+	-	-	-	-
(Olkkonen 1993)	W	Finland	R, CS	All	All	200	+	-	-	+	-
(Orsi et al. 2013)	W	Germany	R, CS	All	All	44	+	-	-	-	-
(Oström et al. 1993)	W	Sweden	R, CS	All	All	146	+	-	+	-	+
(Randhawa 2010)	D	UK	N	A	F	1	-	-	-	+	-
(Randhawa et al. 2013)	D	UK	N	A	All	2	-	-	-	-	-
(Rodgers 1995)	W	USA	R, CS	All	All	917	+	-	-	-	+
(Rowe et al. 1995)	W	Canada	R, CS	All	All	212	+	-	-	+	+
(Schimek 2014)	G	USA	R, CS	All	All	793	+	+	+	+	-
(Sentinella and Keigan 2005)	G	UK	R, CS	C	All	90	+	+	-	-	-
(Sjöegren et al. 1993)	W	USA	R, CS	A	All	55	+	-	-	+	+
(Spence et al. 1993)	W	Canada	R, CS	C	All	81	+	+	+	-	-
(Transafety Reporter, (1989)	G	USA	R, CStudy	C	M	1	-	-	-	+	-
(Valentine and Tillman 2010)	D	USA	N	A	All	10	+	-	-	-	+
(US Dept Transport'n, (1994)	D	USA	R, CS	All	All	814	+	+	-	+	-
(US Dept Transport'(2013)	D	USA	R, CS	All	All	677	+	-	-	+	-
(Venara et al. 2013)	W	France	R, CS	A	F	1	+	-	-	+	-
(Waller 1969)	G	UK	R, CS	All	All	109	-	+	-	+	+
(Watling et al. 2014)	D	UK	N	A	M	1	-	-	-	+	-
(Webster 2006)	G	UK	R, CS	All	All	49	+	-	+	+	-

General: + reported in article, -, not stated/specified Publication type: D, dirty; G, grey; W, white
Study design: R, Retrospective; N, newspaper study; CC, case-control; CS, case series; CStudy, Case study
Comparison group: -, no comparison group, DC, deceased cyclist; DORU, deceased other road user; NFC, nonfatal cyclist; NFORU, nonfatal other road user; FNF, fatal and nonfatal other road users
Age: All, all ages; A, adults only; C, children only Sex: All, both male and female; M, male; F, female

Table 3. Contributing factors in cyclist fatality crashes by Safe System approach

Safe people	Safe roads and roadsides	Safe vehicles	Safe speeds
Helmets+++ **Substance misuse – alcohol, drugs**+++ **At fault**++ **Fail to yield**+ **Failed to see**+ **Violation**+ **Overtook too closely**+ **Misjudgement**+	**Intersections**+ **Poor light**+	**Vehicle type**+ **No lights/reflectors**+	**Excessive speed for conditions**+ **Excessive speed for skill**+
Lost control, Position on the road, Fall, Impairment – age related, Clothing – no high visibility/reflective, Development child (physiological/ cognitive), Inexperience – cycling, Unexpected behaviour, Faulty – driving, Car door, Visual obstruction	No street lights, Location – metro/non-metro, Surface, Road furniture, Land use	Mechanical failure, Blindspot	High speed zones
Failed evasive manoeuvre, Distraction/inattention, Impairment – health related, Impairment – temporary, Knowledge of road rules, Clothing – footwear, Fatigue, Thrill seeking/risk taking, Bike path – incorrect use, Inexperience – driving, Race related, Expectation, Driver training (inadequate)	*No bike lane, Roadworks, Traffic volume*	*Vehicle design, Side protrusion, Bike – load, luggage*	

Number of publications (range) that identified factor: italics <3, plain text 3-10; + 11-20; ++21-30; +++: >30

3.3.2 Safe System factors – Safe Roads and Roadsides

Ten factors were identified in the safe road and roadsides category. Intersections were frequently identified as the location of urban cyclist fatality crashes (Cross and Fisher 1977, Olkkonen 1993, Sjöegren et al. 1993), particularly when heavy vehicles and cyclists shared the space or the driver sight line obstruction (Keigan et al. 2009). Cyclist fatality crashes on rural roads were more likely to occur at non-intersections where speed, obstructed sight lines or road curvature were factors and provision of bike lanes or road widening were considered cost prohibitive (Cross and Fisher 1977, Fraser et al. 2012).

Lighting conditions were a key contributing factor, with the risk of fatal outcome several times greater at dawn/dusk and night time compared to in daylight (Waller 1969, Noordzij 1976, Cross and Fisher 1977, Attewell and Dowse 1992, Bíl et al. 2010). During low light times drivers were more likely to fail to see cyclists (Rowe et al. 1995, Schimek 2014) particularly for night time crashes that occurred on rural roads that had no street lighting (Fife et al. 1983) and high speed limit (e.g. 100 kph)(Noordzij 1976, Hoque 1990).

Poor road surface, damaged or broken surfaces, were contributive in cyclist-fall crashes (Venara et al. 2013). Also identified were: roadworks/temporary road changes need to consider how cyclists can safely navigate the altered space (Transafety Reporter 1989) and on-road structures (Morgan 2014) as well as roadsides, in particular poor sight lines obstructed by road design, parked cars or roadside vegetation (Cross and Fisher 1977, daSilva et al. 2002, Akhtar et al. 2010). Unintended consequences of roadside furniture were also a factor (e.g. cyclist crushed against fencing at a roundabout) (Webster 2006, Moore-Bridger 2010).

Off-road cyclist fatality crashes were largely absent from the examined publications. We were unable to determine if this absence was because few fatalities occurred off-road or because data used in the publications was limited to on-road crashes.

3.3.3 Safe System factors – Safe Vehicles

The majority of all cyclist fatality crashes involved a collision with a motor vehicle. The main focus of motor vehicle safety was on vehicle occupants, with little attention given to the safety of non-occupants including cyclists, motorcyclists and pedestrians(Ackery 2012).

Large vehicles were involved in a disproportionate number of cyclist fatality crashes(Morgan Andrei et al. 2010, Kelkka and Toivonen 2011, Ackery 2012). Over half of the publications reported heavy vehicle crash involvement (53.4%) and these crashes were more likely to result in a fatality compared to crashes with other vehicle types (Kim et al. 2007, Kelkka and Toivonen 2011). In relation to their traffic volume, heavy vehicles were estimated to cause up to 30 times as many cyclist deaths as cars and 5 times as many as buses (Gilbert and McCarthy 1994, Morgan Andrei et al. 2010). Crash contributing factors included larger physical dimensions of the vehicle (Moore-Bridger 2009, Akhtar et al. 2010, Moore-Bridger 2010, Ackery 2012) and the unguarded wheels (Cross and Fisher 1977, Hutchinson and Lindsay 2010, Lydall 2014). In several cases, cyclists were dragged as the driver was unaware they had hit the cyclist (Dix and Bolesta 1988, Klintschar et al. 2003, Akhtar et al. 2010, Randhawa et al. 2013). Side mirrors had also struck the cyclist as the vehicle passed (Cross and Fisher 1977, Fife et al. 1983, Akhtar et al. 2010, Hutchinson and Lindsay 2010).

A bicycle with no or inadequate lights was identified in night time crashes, particularly in areas with no street lighting (Noordzij 1976, Cross and Fisher 1977, Fife et al. 1983, Hoque 1990, Olkkonen 1993, Fraser et al. 2012, Schimek 2014). One study reported two thirds (67%) of cyclist fatality crashes involved a bike with no lights (Attewell and Dowse 1992).

3.3.4 Safe System factors - Speed

Speed was a major contributing factor in cyclist fatality crashes (Bíl et al. 2010). Three key factors were identified in relation to speed: excessive speed for conditions, excessive speed for skill level (typically in relation to cyclists) and posted speed limit being too high. Kim et al (2007) reported when estimated vehicle impact speed is greater than 60km/h the probability of a cyclist fatal injury increased by more than 11-fold.

Excessive speed was identified for both cyclists and drivers. Cyclist excessive speed related to a range of crash events including losing control in a race (Abt 1995), cycling downhill (Attewell and Dowse 1992, Abt 1995, Akhtar et al. 2010) collisions with stationary objects/vehicles (Hutchinson and Lindsay 2010), and riding at speed through an intersection (Sentinella and Keigan 2005). Driver excessive speed was typically related to the posted speed limit (Bernhoft 1994, Keigan et al. 2009, Bíl et al. 2010).

4. Discussion

This systematic review examined 71 publications that reported contributing factors to fatal cyclist crashes. These publications were conducted internationally over a period exceeding 45 years and 52 contributing factors were identified within the Safe System approach. Over half of the contributing factors related to behaviours of the cyclist and/or counterpart. Most frequent were absence of helmets and impairment from substances. There was a general consensus helmet non-use increased the risk of a fatal outcome. Similarly, there was a consensus that impairment, particularly alcohol intoxication by the counterpart driver, was a contributing factor. Other behavioural factors shown to be contributory included: poor conspicuity of the cyclist and/or the bike; other impairment of the cyclist or counterpart driver due to their age, physical health or fatigue; and cyclist and/or counterpart violations or errors.

A further ten contributing factors were identified related to roads and road sides. In urban environments, fatal cyclist crashes frequently occurred at intersection, particularly when co-occurring contributing factors were present such as road design, road user behaviour or the counterpart was a heavy vehicle. Cyclist conspicuity was identified as a contributing factor at low light times or locations. Other contributing factors included poor road surface, road curvature or road side objects obstructing the driver’s vision of the cyclist.

Eight contributing factors identified were related to vehicles. Heavy vehicles were reported as being involved in crashes resulting in death given not only their mass but also the presence of the visual obstruction created by the height of the vehicle from the road. With respect to the bike, poor conspicuity from the absence of lights and reflectors was cited in many of the publications as a contributing factor. Speed in excess of the posted limit, the prevailing conditions and/or skill level was also shown to be an important contributing factor for both the cyclist and counterpart driver. Speed exceeding 60km/hour was posited in one study as an important threshold for injury outcomes for cyclists. Three additional factors were identified as contributory outside of the Safe System approach (lighting, weather conditions and traffic volume).

4.1 Implications

The Safe System framework has advanced the approach to road safety by considering the risks and points of intervention across the transportation system. Overemphasis on road user behaviour immediately prior to a crash often failed to identify the broader systemic issues. Further, scientific research evidence over the last two decades has influenced the introduction of laws to address two major behavioural factors: absence of helmets and impairment from substances.

Many factors that contribute to cyclist fatality crashes are identified in this study, however in Australia, most of these factors are missing from the public policy approach to improving cyclist safety. The rationale for these omissions is not clear. It is possible that a population approach has been taken to road safety, that is action to achieve the maximum benefit for the greatest proportion of the population and as cyclists are too few, they have been excluded from mainstream policies. However, the benefit of cycling and need for a safe cycling environment extends beyond road safety. Action to achieve safer cycling needs to be considered in the broader context of the benefits gained at an individual and societal level from improved health, vehicle congestion, environmental, economic and social mobility perspectives. Integration of cyclist safety into the current policy framework, including road safety, is needed to achieve meaningful improvements in the cycling environment in countries with low levels of cycling participation including Australia.

5. Conclusions

This study provides the first systematic review of the English language literature on factors that contribute to cyclist fatality crashes. Findings from this study can be used to understand cyclist fatality crashes from a Safe System perspective and inform public policy to improve cyclist safety. While the major factors that contribute to many road crashes, alcohol/drug misuse, speed, distraction and fatigue are also prevalent in cyclist fatality crashes, other cyclist-specific factors need to be specifically targeted to improve cyclist safety. The many factors that contribute to cyclist fatality crashes have been considered, however the review has focussed only on fatality crashes. It is likely the factors that contribute to nonfatal crashes differ from those identified here. Further research is required to identify the contributing factors in nonfatal cyclist crashes.

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Chain of responsibility and the heavy vehicle freight industry: benefits, challenges and opportunities

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Abstract

Australia is largely unique in its approach to heavy vehicle regulation. It is one of the few modern democracies not to use operator licensing as a regulatory tool in the heavy vehicle freight industry. Instead, it uses the concept of "chain of responsibility" (CoR). CoR has been a feature of Australia's regulatory approach since the 1980s and is now embedded in the heavy vehicle national law (HVNL) on the eastern seaboard and in recently introduced Western Australian legislation.

Drawing on the experience of Australia's largest freight carrier, Toll Group, this session will explore the benefits, challenges and opportunities presented by CoR. Toll Group has embraced CoR as a key market differentiator and safety driver and is recognised as an industry leader in the promotion of CoR along the supply chain.

Questions tackled in the session include:
*How is CoR changing the Australian freight industry?
*What are the gaps, limitations and challenges in CoR as a regulatory and operational tool?
*What do we need to drive the opportunities presented by CoR further?

Introduction

Australia is highly unusual in that it does not have an operator licensing system in road freight. Consequently, unlike air freight, shipping and rail freight, barriers to entry in road freight are quite low. Establishing a road freight business requires only a vehicle, an ABN and the requisite class of driver licence. Australia is in a minority of OECD countries in not having an operator licensing system, with such schemes operating in the United Kingdom, United States, Canada, New Zealand and several Scandinavian and Nordic countries including Finland.

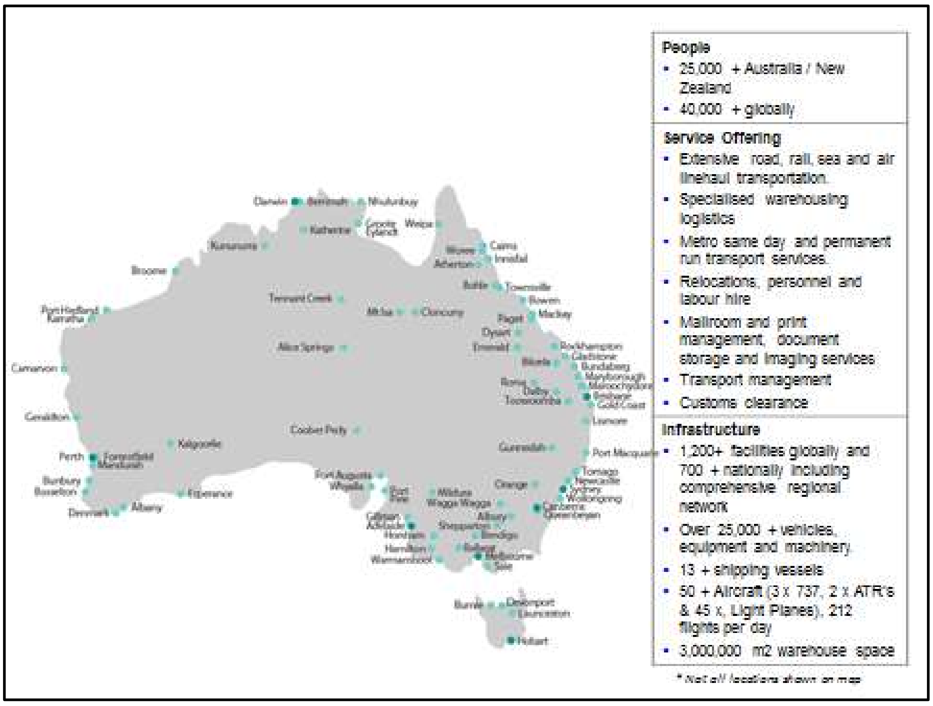
Rather than operator licensing, Australia has “chain of responsibility” (CoR). This legal concept is largely unique to Australia. It recognises that a driver’s on-road behaviour can be influenced by off-road parties. Off-road parties can exert influence through inducing or coercing unsafe and non-compliant behaviour and by omitting or neglecting to do important safety related tasks. For example, an unscrupulous operator might offer a driver financial incentives to speed, or stipulate delivery times that effectively require speeding or flouting of the fatigue rules to meet. CoR works by identifying the parties in the supply chain with influence over drivers and on-road outcomes and making them visible and legally accountable.

This paper explores how CoR is intended to work, to what extent it has impacted road safety outcomes, how Toll Group has responded to the benefits and opportunities presented by CoR, and the limitations of, and tensions in, the current regulatory framework. The difficulties inherent in disaggregating the impact of CoR initiatives from other, concurrent safety and compliance initiatives (explored within the paper) mean that it is difficult to quantify the impact of CoR on safety outcomes. Of necessity, then, the paper is more speculative than scientific in its approach.

About Toll Group

Toll Group commenced operations in 1888 and has grown to become Australia's largest freight company. It now operates nearly 3000 heavy vehicles in Australia. These vehicles travel around 300 million kilometres delivering 54 million consignments each year. Figure 1 below indicates the scale and spread of Toll's Australian operations. Its size makes it a-typical in the road freight industry which is dominated by small to medium enterprises. Approximately 70% of operators have only one truck, around 24% of operators have between 2 and 4 trucks and less than 0.5% of fleets have more than 100 trucks (NTI, undated). Owner/operators account for around 60% of the industry yet around 11% of the profit (Quinlan and Wright, 2008).

Figure 1. Toll Group operations in Australia



How Chain of Responsibility Works

CoR is a concept embedded in the Heavy Vehicle National Law (HVNL). The HVNL became operational in February 2014 and is administered by the national heavy vehicle regulator (NHVR) based in Brisbane. However, CoR is not new. It has existed on the eastern seaboard since the late 1980s and was "mainstreamed" through model laws in the 2000s. The HVNL now applies in all states except the Northern Territory and Western Australia. (Western Australia introduced its own CoR laws through a separate statutory instrument in April 2015. However, unlike the HVNL these laws do **not** apply to speed or fatigue, only to mass, dimension and load restraint).

Chain of responsibility works by imposing specific duties or obligations on parties in the supply chain. When specific duties are imposed, those parties are required to do (or not do) certain things. In some cases, evidence that a driver breached a road law can be taken to mean that off-road parties were also in breach. This is known as 'extended liability'.

For example, if a driver of containerised freight is on a road without a complying container weight declaration (as required by law), then the consignor may be held liable. Similarly, where a load manager's estimates of when a vehicle will be unloaded are incorrect by more than half an hour, the driver must be able to take rest at that facility. The driver does not have to be charged with an offence for proceedings against other parties to be instigated.

Chain of responsibility obligations apply to vehicle operations involving vehicles over 4.5 tonne, except in the case of fatigue obligations which apply to vehicles 12 tonne and above. Obligations are placed on parties in the chain in relation to:

- mass requirements
- load restraint requirements
- dimension requirements
- speed management
- fatigue management
- heavy vehicle accreditation, and
- vehicle operations.

The law requires that supply chain parties use their influence to promote compliant, safe behaviour. However, the law also recognises that there are practical limits to the influence of even the most diligent individual. Despite best endeavours, mistakes can still happen and other parties may remain ignorant of their responsibilities or deliberately break the law. For this reason the HVNL provides a 'reasonable steps defence'. As far as the law is concerned, even if an accident or a breach occurs, if a party can demonstrate that they took all reasonable steps to prevent it, then they have fulfilled their responsibilities.

As a defence, reasonable steps only applies where:

> You did not know, and could not reasonably have been expected to know, of the contravention concerned; **and**
> Either
> You took all reasonable steps to prevent the contravention; **or**
> There were no steps you could reasonably have been expected to take to prevent the contravention.

The law requires all reasonable steps to be taken. Not some, but *all* reasonable steps. Ultimately, in the event of a breach, it is for a court to determine what is 'reasonable', and herein lies one of the limitations of the current regulatory framework. Presently, most CoR-related determinations are made at the magistrate or local court level. 'As these courts do not produce any systematic and frequent public reports there [is] little readily available guidance as to the way in which these courts will…consider the application of the taking of reasonable steps.' (Lord Commercial Lawyers, 2014). Unless the matter progresses to a higher court, the vast bulk of determinations about what is 'reasonable' are inaccessible to industry.

The HVNL has a reverse onus of proof, which means that the onus is on the defendant to prove they took reasonable steps rather than on the prosecution to prove they did *not*. This has been criticised, including by the Queensland Law Society, as contrary to natural justice and the principle of 'innocent until proven guilty' (Queensland Law Society, 2012). However, Toll's view is that the reverse onus gives industry the freedom to adopt the reasonable steps that work for its particular circumstance. Industry itself is best placed to articulate the case for why its systems and processes are appropriate.

What impact has Chain of Responsibility had on road safety?

It is difficult to precisely disaggregate the role that CoR plays in reducing road trauma from that played by improved vehicle design, better road systems and management, technological innovation and enforcement. Nonetheless, there is credible evidence that the regulatory framework is positively impacting on road safety in the heavy vehicle industry. A 2013 NTC report claimed that CoR investigations are 'the most potent instigator of structural and cultural change currently available' in the industry (NTC, 2013). In support of this view is:

- a 10% reduction in fatalities involving heavy vehicles achieved between 2006 and 2012 (BITRE, 2012)
- a 35% improvement in the incidence of serious crashes involving a heavy vehicle, adjusted for inflation, since 2002 (NTARC, 2015)
- a reduction in fatigue as the cause of accidents from 20% in 2007 to 12.8% in 2013 (the fatigue CoR laws were introduced in the eastern states in 2008 so there is a correlation between the introduction of the laws and the reduction in fatigue-related accidents) (NTARC, 2015)
- Western Australia's comparatively high rate of fatigue-related incidents. WA – which does not have a CoR approach to fatigue but instead manages fatigue through a code of practice – accounts for 30% of all fatigue-related incidents in Australia (NTARC, 2015). Western Australia moves around 19% of Australia's domestic road freight. (BITRE, 2014).

However, there is also evidence that industry risks remain unacceptably high and that other regulatory frameworks are performing better, for example

- in the period that Australia achieved a 10% reduction in fatalities involving heavy vehicles, the United States (which has an operator licensing system) achieved a 26% reduction (Ferro, 2012) (Admittedly, the global financial crisis in the United States significantly affected the vehicle kilometres travelled).
- while heavy vehicle incidents involving a fatality are trending downwards, incidents involving hospitalisation are trending upwards (Department of Infrastructure and Regional Development, 2014)
- there is no industry more dangerous for an Australian to work in than transport and logistics (ABS, 2011)
- speed and fatigue continue to be significant factors in road deaths involving a heavy vehicle (Standing Committee on Transport, 2010; NSW Centre for Road Safety, 2014)
- the economic cost of road crashes in Australia is around $27 billion per year (Department of Infrastructure and Regional Development, 2014). The human cost in terms of grief, loss and trauma is incalculable.

It is Toll Group's contention that more can and should be done to reduce the social and economic cost of road-related injury and death (Toll, 2015).

Toll Group's approach to Chain of Responsibility

Toll Group's way of doing business is governed by a company philosophy or set of values called 'the Toll Way'. The Toll Way includes that:

- all injuries are preventable and everyone has a right to go home safely
- how we go about achieving success is as important as success itself
- we must act ethically and within the law
- we will not always get things right and learning from our mistakes is part of our progress

The benefit of embedding safety in the corporate philosophy is that it has encouraged reporting and management attention on factors additional to more traditional industry KPIs, such as 'delivered in full-on time' (DIFOT). Toll's pre-existing emphasis on safety and compliance meant that the CoR concept was relatively easily absorbed within the corporate culture, rather than being in tension with it.

Toll Group consciously approaches CoR as an opportunity to demonstrate leadership in the industry, and as a market differentiator. Beyond this, Toll has adopted a stance that might be described as 'pseudo-regulatory'. That is, Toll is attempting to influence the supply chain towards compliance through a mix of persuasion, education and discipline; levers that are usually the preserve of regulatory bodies. The risk posed to Toll Group as a prime contractor, as well as the particular circumstances in which the national heavy vehicle regulator (NHVR) commenced, influenced the pseudo-regulatory stance.

As noted above, the bulk of the industry consists of smaller operators. Toll Group subcontracts work to these operators where it cannot manage demand within its own fleet. So, for example, Toll NQX has around 800 subcontractors on its books who may complete one or thousands of routes each year. This makes Toll a prime contractor as understood within the HVNL, with all the attendant obligations and duties. Subcontractors are vetted and audited by Toll to ensure they operate consistently with Toll's values and compliantly with the law. Such measures provide an incentive for industry compliance. After all, operators that wish to work for Toll must demonstrate that they can do so consistent with the law. This illustrates how a party – in this case a prime contractor - can exert its influence to promote change along the supply chain.

When the NHVR commenced operations in February 2014, the industry looked to regulatory bodies for guidance on how to comply with law. That this guidance is *supposed* to be provided is implicit in the responsive regulation model on which the *Compliance and Enforcement Bill of 2003* was based (NTC, 2013). However, the operational difficulties experienced by the NHVR when it commenced meant that resources were directed towards core functions like permitting. Educational material was a secondary consideration. This left Toll Group with a dilemma: to wait for the NHVR to build the capacity to produce the material, or to step into the breach and develop such material in-house?

Ultimately, Toll elected to develop guidance material. This material is both in-house for Toll staff, and external for customers and clients along the supply chain. The internal material includes a *Guide to CoR for Toll Managers*, a quarterly *Road Transport Compliance Newsletter* (which includes analysis of CoR court cases) and modularised online training. This training was developed by Toll in partnership with an online training provider. The external material includes brochures designed to promote customers' understanding of their obligations in the supply chain. Figure 2 illustrates the brochures, one for the HVNL states and one for Western Australia. The brochures have proven popular and have been acknowledged by both the NHVR and the NTC as filling an information-void.

Figure 2. CoR material for external stakeholders

The decision to provide CoR guidance to external parties was the subject of some debate within Toll Group. After all, assuming the role of 'expert' assumes that one's own house is in perfect order. Yet Toll can, and does, make mistakes. These mistakes can be amplified by Toll's pseudo-regulatory posture. Toll finds, for example, that when it hosts CoR customer information sessions it subsequently receives calls from stakeholders who were in attendance and who, on reflection, feel that Toll could have handled particular situations better. Rather than being defensive about this feedback, Toll tries to approach it as CoR in action: an exchange of information along the supply chain which, properly handled, leads to better outcomes for all parties.

An example of the way in which Toll pulls the 'pseudo-regulatory' levers available to it is through rating its subcontractors on the basis of audit results. Subcontractors that do not meet the standards Toll expects are placed on a 'do not use' list until the identified issues have been rectified. Many subcontractors are equipped with the speed-detection and GPS tracking systems utilised by Toll to track and manage speed and fatigue events. Recently, Toll made the difficult decision to cease servicing a customer whose pallet stacking practices were deemed to pose a risk to the safety of Toll staff. After several months, this incident ultimately resulted in a change of practice at the customer site and a re-forming of the relationship – a good example of how 'holding the line' on safety can yield positive results.

It is difficult for Toll Group to precisely quantify the impact its approach to CoR has had, and is having, on its road safety record. As with the transport system generally, it is difficult to disaggregate the impact of CoR compliance initiatives from technological and other innovations. Further, Toll's business units often operate fleets consisting of both light and heavy vehicles, only the latter of which fall within the CoR framework (except in WA). Nonetheless, there is solid evidence for safety improvements being delivered at Toll Group that correlate with its approach to CoR. For example:

- In 2001 Toll Group's lost time injury frequency rate (LTIFR) was 50 per million hours worked. In 2014, the LTIFR was 1.81
- Toll's externally detected road transport breaches for heavy vehicles fell by nearly 340% between 2013 and 2015
- The most recent reporting period saw only one internally detected mass breach across Toll
- Toll NQX (one of Toll's business units operating exclusively heavy vehicles) experienced a reduction in internally detected speed events of 570% between June 2013 and June 2015 following the instalment of in-vehicle cameras. Motor vehicle incident frequency rates nearly halved between December 2011 and April 2015 (Smith and Jones, 2015)

Limitations and Challenges of CoR

Safety and Price

As noted in the section above, Toll Group has made considerable investment in CoR initiatives. It also deploys monitoring and reporting systems for speeding, fatigue and driver distraction (Law, 2015; Smith, 2015). Theoretically, this investment should make Toll and other similarly-minded operators an attractive choice of carrier in the marketplace. After all, the HVNL implies, though does not explicitly state, that parties looking to transport goods via road must make their choice of carrier on factors other than price alone. For example, consignors and consignees are required to make 'reasonable inquiries' of the scheduling process to ensure that drivers are not incentivised to speed, drive while impaired by fatigue or otherwise act in ways that might compromise safety.

But how many of them do this? Sharon Middleton, the President of the South Australian Road Transport Association (SARTA) expressed a view that customers may 'go for the cheapest rates, often regardless of quality and even despite poor compliance and safety of the truck operator' (Middleton, 2014). This may be a financially "rational" decision from the customer's perspective, albeit it contravenes the spirit and the letter of the HVNL. For CoR to effectively embed cost of compliance and safety into price two things would need to happen: consumers need to be in a position to make sound choices, and enforcement needs to tackle that segment of the industry that cannot or will not comply, and accrues a competitive advantage as a result.

The United States has creatively solved the former problem by arming customers and stakeholders with credible and sufficient data to make informed decisions. The United States Department of Transport collects and analyses operator performance-related data and hosts it on their website. In 2009 this data was viewed in nearly four million user sessions and is credited with producing the most dramatic improvement in non-compliance ('violations') in the last decade (Ferro, 2012). Australia attempted to do something similar with the Five Star Trucking initiative (now disbanded) but was stymied by (among other things) the partial and incomplete nature of the data. Not having an operator licensing system, Australia collects little to no information about operators at point of entry. What data is collected derives from vehicle registration, enforcement activity and periodic surveys conducted by peak bodies and regulatory authorities.

As argued in Jones (2015), consistent, visible and effective enforcement of the law is essential to address systematic non-compliance. While it may appear odd for industry to lobby for more enforcement, this is essential if those operators that cannot or will not comply with the law are to be forced out of the system. While they are allowed to operate, they have a competitive advantage over organisations that take safety and compliance seriously.

CoR enforcement varies widely across Australia. Although CoR investigations are acknowledged as drivers of cultural change in the industry (NTC, 2013) they are also expensive and high risk when compared to more traditional forms of enforcement such as on-the-spot fines. A successful CoR prosecution against supply chain parties can take years, and requires the prosecution to prove that the defendant did not take ‘reasonable steps’ to prevent a contravention. At the time of writing, there was only one CoR investigation ongoing by VicRoads (Skinner, 2015). In the entire time that CoR has been operational in Victoria, there has never been a successful CoR prosecution for fatigue (Skinner, 2015). In such circumstances, the deterrence effect of the law is questionable.

Roadworthiness

It is counter-intuitive that a business that relies on its vehicles to transport freight would neglect the maintenance of those vehicles. However, transport freight is an industry in which margins can be tight and most costs (such as labour and fuel) are fixed (Mayhew and Quinlan, 2006). One of the few expenses that can be ‘cut’ is vehicle maintenance. Taking vehicles off the road for servicing carries an opportunity cost: while off the road that vehicle is non-productive. Reactive maintenance (including recovery) is often at the most inconvenient times and can incur financial penalties from the client if delivery is not completed within quoted schedules. For these reasons, operators may run vehicles beyond manufacturer specifications.

The data suggests that some operators are not appropriately investing in the care and maintenance of their vehicles. The proportion of heavy vehicle inspections that find major defects is estimated at between 0.46% and 9.75% (NTC, 2015). It is very difficult to extrapolate from defects to crash risk, and Toll believes that the case for a strong link hasn’t been made (Toll, March 2015). However, where mechanical defects do contribute to accidents, the results are often catastrophic and highly visual; generating public and political attention. The National Truck Accident Research Centre estimates that mechanical issues cause accidents in about 5% of cases (NTARC, 2015).

Operators have a legal obligation to maintain their vehicles to a roadworthy standard, which means that the vehicle must be compliant with the Australian design rules and the Australian vehicle standards regulations. However, there are no CoR obligations attached to roadworthiness. Thus, there is no obligation in the HVNL for parties in the supply chain who influence/effect roadworthiness (such as mechanics and vehicle modifiers) to take reasonable steps to ensure vehicles are well maintained.

Nor are operators required to demonstrate the financial capacity to maintain vehicles *before* the vehicle is on the road. Even the maintenance module in the national heavy vehicle accreditation scheme (NHVAS) only requires an operator to demonstrate that they have maintenance *systems*, not maintenance *liquidity*. This is in contrast to the United Kingdom, where operators must demonstrate their ‘financial standing’ before they are permitted to operate. Operators must demonstrate that they have £7400 (AUS $13,894) for the first vehicle and £4100 (AUS $7,698) for each additional vehicle (UK Traffic Commissioner).

In Australia, financiers are not recognised parties in the chain. Banking and credit institutions that lend funds to businesses to purchase trucks are under no obligation to ensure that the cost of maintenance is factored into the lendee’s capacity to service the loan. If vehicle safety is brought under the CoR regime (which seems likely) questions remain as to how, or if, it can compel fleet managers to spend what is required on vehicle maintenance. An idea mooted by the Technical Working Group on Roadworthiness was that financiers be named as parties in the chain; the rationale being that the finance arrangements between lenders and truck purchasers should go beyond interest repayments to include vehicle maintenance.

Conclusion

CoR has been operational in large parts of Australia for more than two decades. There is sound evidence that it has, and is, making a positive impact on the safety of the Australian road freight industry. Toll Group has embraced the opportunities afforded by CoR and adopted a 'pseudo-regulatory posture in relation to CoR. This posture arose from an aspiration to be recognised as a leader in the industry, because it was consistent with Toll's philosophy and safety culture and to redress an information vacuum. Nonetheless, important questions remain as to the capacity of the current regulatory framework to prompt consumer decisions on factors other than price and to ensure vehicle roadworthiness. The inaccessible nature of court decisions about what is 'reasonable' is a further limitation.

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Proposed vehicle impact speed - severe injury probability relationships for selected crash types

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Abstract

Speed is recognised as a key contributor to crash likelihood and severity, and to road safety performance in general. Its fundamental role has been recognised by making Safe Speeds one of the four pillars of the Safe System. In this context, impact speeds above which humans are likely to sustain fatal injuries have been accepted as a reference in many Safe System infrastructure policy and planning discussions. To date, there have been no proposed relationships for impact speeds above which humans are likely to sustain fatal or serious (severe) injury, a more relevant Safe System measure.

A research project on Safe System intersection design required a critical review of published literature on the relationship between impact speed and probability of injury. This has led to a number of questions being raised about the origins, accuracy and appropriateness of the currently accepted impact speed–fatality probability relationships (Wramborg 2005) in many policy documents. The literature review identified alternative, more recent and more precise relationships derived from the US crash reconstruction databases (NASS/CDS).

The paper proposes for discussion a set of alternative relationships between vehicle impact speed and probability of MAIS3+ (fatal and serious) injury for selected common crash types. Proposed Safe System critical impact speed values are also proposed for use in road infrastructure assessment. The paper presents the methodology and assumptions used in developing these relationships. It identifies further research needed to confirm and refine these relationships. Such relationships would form valuable inputs into future road safety policies in Australia and New Zealand.

Introduction

Speed is recognised as a key contributor to crash likelihood and severity, and thus, to overall road safety performance. Its fundamental role has been recognised by making Safe Speeds one of the four pillars of the Safe System, and is given a focus in many policy documents including the National Road Safety Strategy 2011-2020 (Australian Transport Council 2011). Since the late 1990s, impact speeds above which humans are likely to sustain fatal injuries have been adopted in many Safe System infrastructure policy and planning discussions. Since then, there has been no revision of these in the context of the actual Safe System objective of minimising the risk of fatal or severe injury.

In an Austroads project on safer intersections, Jurewicz, Tofler and Makwasha (2015) reviewed recent research on this subject raising questions about appropriateness of the existing impact speed–fatality probability relationships as basis for future road safety strategies. Alternative relationships, based on probability of a fatal or serious injury outcome given vehicle impact speed, have been proposed on the basis of more recent research carried out in the US. Further discussion and refinement of these relationships is needed in order to fully address the local demands of the Safe System implementation. One relationship worthy of refinement includes the nature of the vehicle fleet and mix of vehicles on the road.

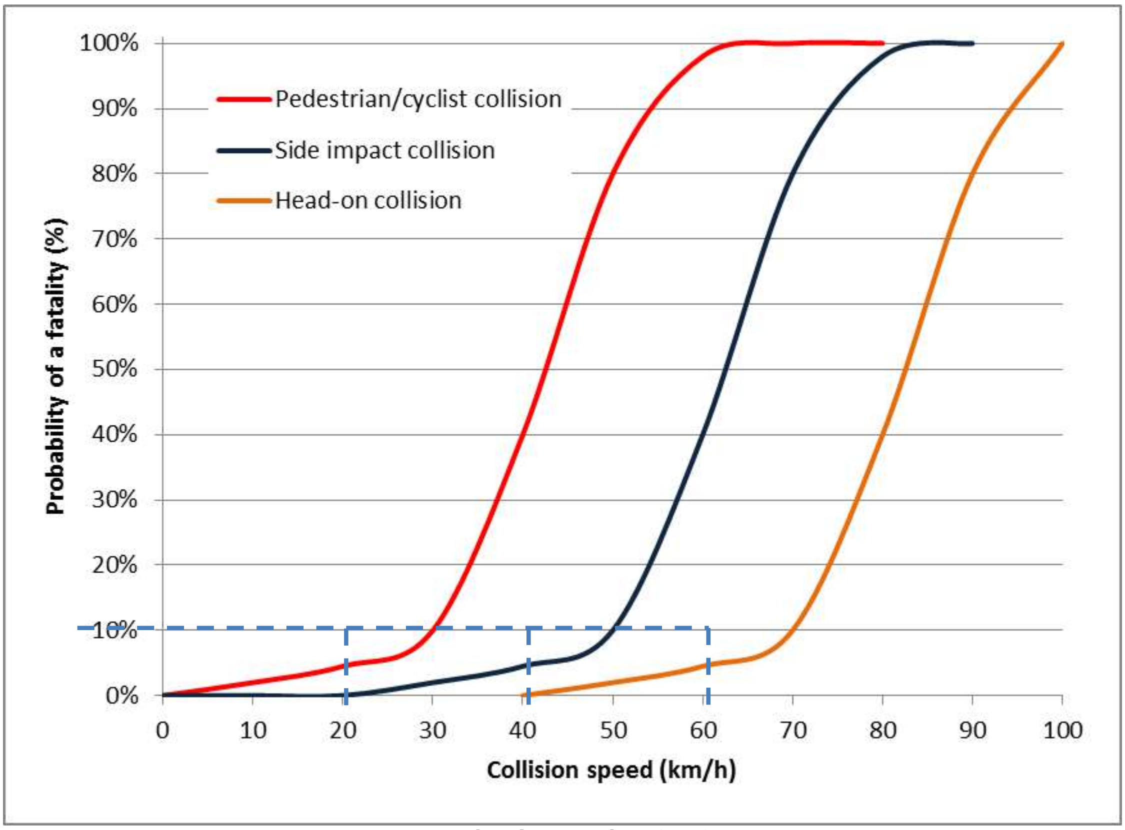
Review of existing relationships

The role of speed in crash likelihood has been confirmed through numerous studies. For example, Nilsson (2004) and then Elvik (2013) demonstrated that lower mean traffic speeds in response to speed limit reduction result in reduced likelihood of casualty crashes. Kloeden (2001, 2002) presented relationships demonstrating that the likelihood of driver involvement in a casualty crash increased with his or her speed over the speed limit. Much of this body of research points to the fact that even small speed reductions can lead to considerable reductions in road trauma.

Severity of crash outcomes in response to speed has also been well researched. Studies by Elvik and others, e.g. Elvik (2013), showed that fatal crashes decline more substantially with the same amount of mean speed reduction than all injury crashes. In other words, severity of crashes decreases with reduced mean speed.

One model in particular has been adopted in Australia and New Zealand to illustrate the effect of impact speeds on severity of selected crash types. Wramborg (2005) proposed the three impact speed–fatality probability relationships as shown in Figure 1.

Figure 1. Wramborg's model for fatality probability vs. vehicle collision speeds



Source: based on Wramborg (2005).

These relationships assume that the conflicting vehicles have equal mass and speed. According to these probability curves, there is a 10% chance of fatality outcome when vehicles impact at the following speeds:

- 30 km/h in pedestrian/cyclist crashes
- 50 km/h in side impact collisions
- 70 km/h in head-on collisions.

These speed thresholds were also noted earlier in a conference paper by Tingvall and Haworth (1999). Much of the Safe System infrastructure discussion to date has been based around these thresholds. They are often quoted as the maximum or 'survivable' impact speeds which can be tolerated in relation to intersection design, pedestrian activity areas, or provision of medians.

There are several important issues which limit the applicability of Wramborg's curves. The first issue is that Wramborg's curves only provide information about the probability of fatal injury. As minimisation of both fatal and serious injuries is the key concern of the Safe System vision, any advice on Safe System infrastructure should reference probability of types of severe injury.

The second issue is that little is known about the source of these relationships. The Wramborg (2005) conference paper did not provide any research references or sources of information for the impact speed curves. There was no way of checking these relationships against similar or prior research. The context of the paper is the establishment of the Vision Zero-based road hierarchy in Sweden, and this indirectly suggests that the curves were in use prior to 2005. Tingvall and Haworth (1999) also note the 10% fatality risk threshold speeds, referencing only high-level policy documents and keynote presentations as sources.

The third issue is that the curves in Figure 1 lack clarity. Does the term 'collision' imply a crash involving two or more vehicles, or the impact an individual vehicle has been subjected to? For instance, an adjacent direction crash involves a head-on impact by the bullet vehicle and a side impact into a target vehicle. Further, handling of different crash types is unclear: would an opposing-turning crash be a head-on or side impact? Does the term 'collision speed' refer to the impact speed of one vehicle, or the closing speed of two vehicles (a vector sum of two speeds)? This lack of clarity has led to assumptions in many Safe System policy and implementation discussions (e.g. that 50 km/h is the 'survivable' impact speed in intersection design).

Finally, a common interpretation of Wramborg's curves resulted in 'Safe System speeds' acknowledging a 'minimised' 10% fatality risk. In fact, an average fatality risk in a casualty crash is in the range 1%-7% in 80 km/h speed zones, depending on crash type (Victorian crash data 2008-13, based on uncongested periods between 7 pm and 5 am). Since casualty crashes are a fraction of all impacts, these fatal percentages would be even lower if all impacts were considered. Any Safe System-related design advice needs to result in a stepwise improvement on the current safety performance. Hence, application of Warmborg's curves and this commonly accepted fatality threshold may not be inappropriate for assessment of Safe System alignment of safety solutions.

It may be that Wramborg's impact speed–fatality probability relationships in Figure 1 represent the best evidence available to the road safety community at the beginning of the Safe System discussion in Australia and New Zealand. Given that more than a decade has passed since, and much new research has been published, the relationship between speed and injury severity may be due for review and discussion. This would be prudent given the 2021 horizon for the development of the new National Road Safety Strategy.

Delta-v and Severe Injury Probability

Review of crash reconstruction research suggests that estimated or measured impact speed of a vehicle is generally a poor predictor of crash severity, with the exception of pedestrian and cyclist crashes. It has been well established since the 1970s, that a vehicle's delta-v[1] is closely related to injury severity in two-vehicle crashes, e.g. side impact, head-on or rear-end. The only known drawback is accuracy of estimating delta-v in relation to rollover, roadside hazard and safety barrier

[1] Change in velocity magnitude of a vehicle during the crash.

crashes (Joksch 1993, Shelby 2011, Rosen, Stigson and Sander 2011, Schmitt et al 2014, Struble 2013).

There has been a significant amount of quality empirical research on the effect of delta-v on severity of two-vehicle crashes based on crash reconstruction databases held in the US (NASS/CDS, CIREN) and UK (CCIS, OTS). One of the seminal studies was by Joksch (1993), cited by Evans (1994), who developed a ‘rule of thumb’ power function for probability of a driver fatality given a vehicle’s delta-v. This work was followed by Evans (1994) who used 22 272 crashes from the NASS database to create similar relationships for probability of driver fatality and injury. These relationships were based on crashes occurring between the early 1980s and early 1990s, and did not differentiate between crash types, e.g. head-on, side impact or rear-end. Applicability of these relationships to the three crash types was tested in this project and did not return results which correlated well with other research.

It is also worth noting other relevant studies investigating injury severity and delta-v, such as that by Richards and Cuerden (2009) in the UK. These used smaller crash samples which suffered from lack of statistical power or direct relevance to this project.

Most relevant research on vehicle-to-vehicle collisions was carried out by a group of researchers associated with the National Highway Traffic Safety Administration (NHTSA) in the USA. Augenstein et al. (2003a, 2003b) and Bahouth et al. (2012, 2014) provided much more refined sets of delta-v vs. severe injury probability relationships for occupants of vehicles involved in frontal, nearside (i.e. driver side), far side (i.e. passenger side) and rear-end impacts. These studies used large samples of crashes drawn from ever-expanding NASS/CDS and CIREN databases in the USA (in excess of 100 000).

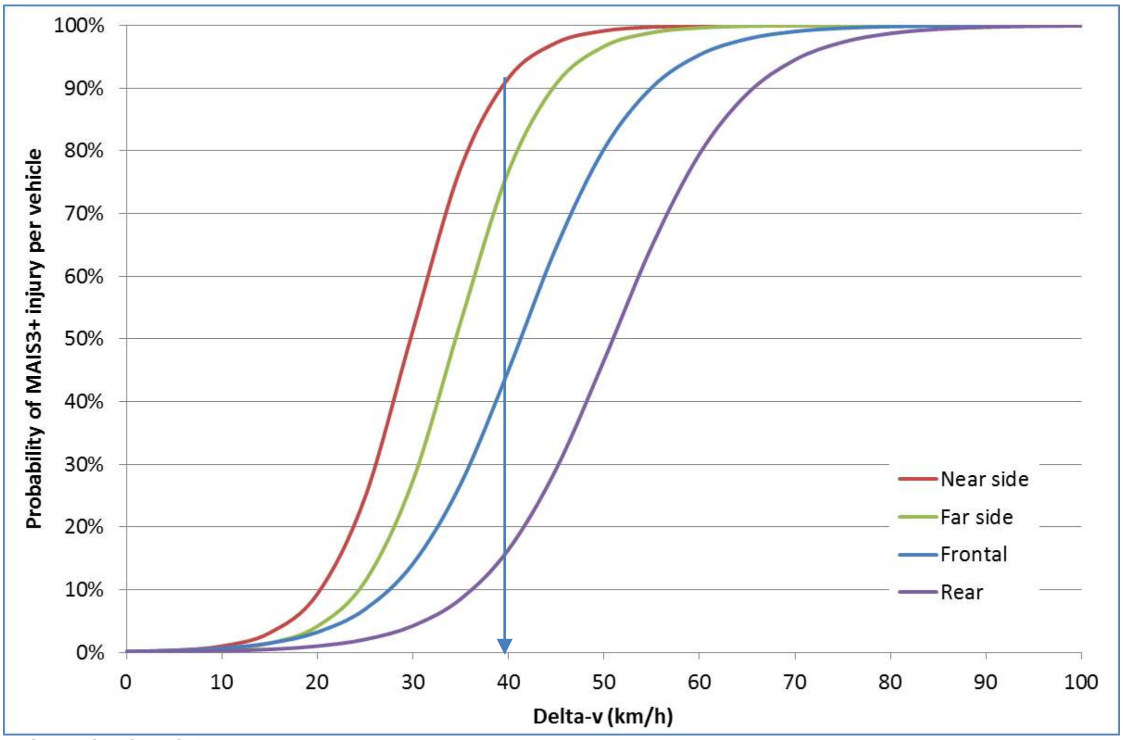
The objective of these researchers was to develop and refine reliable triggers for automated crash notification systems in vehicles. The baseline collision severity used in these studies was a non-injury tow-away crash. The authors applied strict limitations on the crash cases included in analysis to suit their objectives, e.g. availability of delta-v in the NASS records, focus on front seat passengers only, and the age of vehicle. The crash data in NASS/CDS was already weighted to match severity and type of crashes occurring across the USA. Also, all of these studies used a vehicle as a basic study unit, rather than a crash event (two or more vehicles).

Like the earlier studies, the Bahouth et al. (2014) study used logistic regression to develop relationships between probability of a MAIS3+ injury for a front seat occupant of a crashed vehicle in given crash configurations. MAIS3+ is widely considered the serious injury threshold and includes fatality. In this study, the regression models were based on new vehicles (post 2002) and controlled for a range of factors such as: delta-v, seatbelt wearing, rollover, secondary impacts, and age of the front seat occupants. The logistic regression models were developed using a randomly selected 80% of the applicable 2002-2012 NASS/CDS database and validated using the remaining 20% of data.

Figure 2 shows the resulting relationships between probability that a front seat occupant of a crashed vehicle will sustain an MAIS3+ injury and the vehicle’s delta-v for a range of vehicle impact types. These curves assume seatbelt use, no rollover or secondary impacts, and occupant age between 16 and 55. Airbag deployment was not noted, but it can be assumed the vehicles were equipped with such, given the sample consisted of post 2002 vehicles only. Since the authors make no statement on the vehicle types, it is assumed the data set included both passenger and heavy vehicles.

Bahouth et al. note the principal directions of force (PDOF) on a vehicle which were used to categorise each impact into frontal, near side, far side, and rear types. The probability curves in Figure 2 reflect the logical expectations for these cases. For a given delta-v value, the near side impact was the most severe for the occupants. In this scenario, the impact occurs on the side of the driver and the amount of protection offered by the vehicle body is very low. The far side is next, showing the benefit of the crush zone to the left of the driver (assumed empty). Next is the frontal impact, with the crush zone benefit of the engine compartment but also with likelihood of the steering wheel injuring the driver. The least severe impact type is into the rear of the vehicle, with the large and typically empty crush space behind the driver.

Figure 2. Probability of a severe injury of front seat occupants vs. delta-v of a vehicle during a crash



Source: based on Bahouth et al. (2014).

Impact Speeds, Angles and Severe Injury Probability

It is difficult to directly apply the delta-v concept to Safe System road infrastructure discussion. This difficulty stems from the variable being a crash characteristic which lacks a direct relationship to road design inputs. Impact speed has been much more easily understood and related to design speed, or speed limit – variables under control of road agencies. Thus, it was important for this project to develop and demonstrate the generalised relationship between impact speeds, impact angles and severe injury probability. This would enable road agencies to modify this probability through improved design of infrastructure elements.

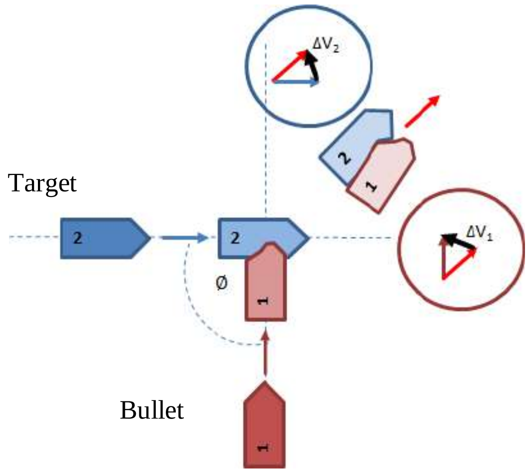
The relationships between delta-v and severe injury probability for different crash types in Figure 2 can be transformed to show the effect of impact speeds if we consider impact angles and several simple assumptions. This way the evidence from the research described in the previous section can benefit further Safe System infrastructure discussion in Australia and New Zealand .

As a first step, a useful derivation of delta-v was provided by Tolouey et al. (2011). Using Newtonian mechanics of momentum conservation, the authors showed that delta-v has the relationship with vehicle masses, impact speeds and the angle between their paths as shown by Equation 1.

$$\Delta V = \frac{m_1}{m_1+m_2}\sqrt{V_1^2 + V_2^2 - 2V_1V_2\cos\emptyset} \qquad (1)$$

where ΔV is vehicle change in speed due to the crash, m1 and m2 are respective masses of 'bullet' and 'target' vehicles, V1 and V2 are their impact speeds, and Ø is the angle between the axis of travel of both vehicles, as shown in Figure 3.

Figure 3. Layout of colliding vehicles in Equation 1.



Newtonian calculation based on Tolouei et al. (2011) in Equation 1 is a very simplistic approximation, as delta-v of an individual crash is a function of many additional factors such as:

- relative masses of the vehicles involved
- part of the target vehicle hit
- vehicle construction and stiffness
- brake application timing and skidding
- vehicle yawing (rotation)
- post-impact rebound, if any.

One of the first assumptions in creating the impact speed–severe injury relationship was to normalise the role of relative vehicle masses in Equation 1. This is not necessarily something which can be easily controlled by road agencies at intersections. The mass ratio affecting delta-v's and severity of injuries for individual vehicles is likely to have a normal distribution, i.e. it will be favourable for some vehicles (large) and worse for others (small). It has been assumed from this point onwards that the masses of the two vehicles are identical. The term m1 / (m1 +m2) in Equation 1 thus becomes ½ and allows sole focus on the role of impact speeds and angles. This assumption would need to be reconsidered when investigating road design for traffic flows with a large percentage of heavy vehicles.

Another assumption in Figure 3 is that the collision is inelastic, i.e. there is no rebound of vehicles. In such cases, delta-v has the same magnitude for both vehicles of equal mass, as they stick together after collision. This assumption leads to a slightly overestimated value of delta-v in side collisions, and hence of the risk. Thus, the critical side impact speeds discussed further on may also be conservative, i.e. slightly lower values than if elasticity was accounted for.

The next step was to use Equation 1 to calculate a delta-v given a known impact speed of a bullet vehicle, assumed speed of a target vehicle, and an approximate impact angle representing a given crash type. Since, the angle is a variable in delta-v (Equation 1), it can be varied to carry out sensitivity analysis.

As noted earlier, Bahouth et al. (2014) provided their results based on individual vehicles in specific impact types (frontal, near-side, etc.), rather than on crash events (two vehicles, two impact types). This limitation was carried over to this project. Thus, using the assumed impact speeds, angles, and delta-v relationships from Figure 2, it was possible to calculate Pr(MAIS3+) for each targeted crash type. This is plotted in Figure 4 together with various assumptions indicating which impact type produced the highest severity[2].

For vehicle-pedestrian crashes, the physics of collision are different. The delta-v principle does not provide a good estimation of injury (Evans 1994). Davis (2001) provided an updated empirical relationship for pedestrian severe injury at different impact speeds. This relationship was chosen from a number of others reviewed by Rosen, Stigson and Sander (2011) on the basis of its relevance (severe injury) and solid methodology.

All five leading severe crash types are shown in Figure 4, with the approximate critical impact speeds in Table 1, and additional assumptions stated in Table 2. For a given bullet vehicle impact speed the pedestrian crash is the most severe, as expected due to biomechanical vulnerability of the target. This is followed by head-on crash, where the very high delta-v outweighs the benefit of the vehicle’s crumple zone. On par is the adjacent direction crash into the near side, where the lower delta-v is offset by greater vulnerability of the driver due his/her position. Next is the opposing-turning crash which assumes the impact on the far side and shows benefits of the passenger space as a crumple zone (see Discussion). The least severe is the rear-end crash type, given the low typical value of delta-v and a large crumple zone. The most critical impact in this case was on the bullet vehicle. These severities follow the order of the average casualty crash severity findings from Jurewicz et al. (2013). The suggested critical impact speeds for each crash type in Table 1 are based on an assumption that a 10% severe injury risk would be a substantial improvement in current safety performance.

Further analysis was carried out for roundabout collisions, where adjacent direction and opposing-turning crash types are essentially the same type of impact (far side). For a typical roundabout with a 70 degree entry and impact angle, and a 40 km/h circulating speed, the critical entry speed would be 30 km/h (or 40 km/h if the circulating speed was 30 km/h). As the entry angle is reduced at some larger sites, the critical entry speed increases. For a roundabout with a 30 degree entry and impact angle, and a 40 km/h circulating speed, the critical entry speed was calculated to be 60 km/h (lower speeds would reduce probability of severe injury below 10%). This demonstrates how geometric design can fundamentally improve safety performance.

These values are indicative only, due to many assumptions and model limitations. They have been rounded to the nearest 5 km/h. The pedestrian-vehicle critical impact speed could be extended to other vulnerable road users (cyclists and motorcyclists) until more specific evidence can be identified.

Table 1. Approximate critical impact speeds for common crash types

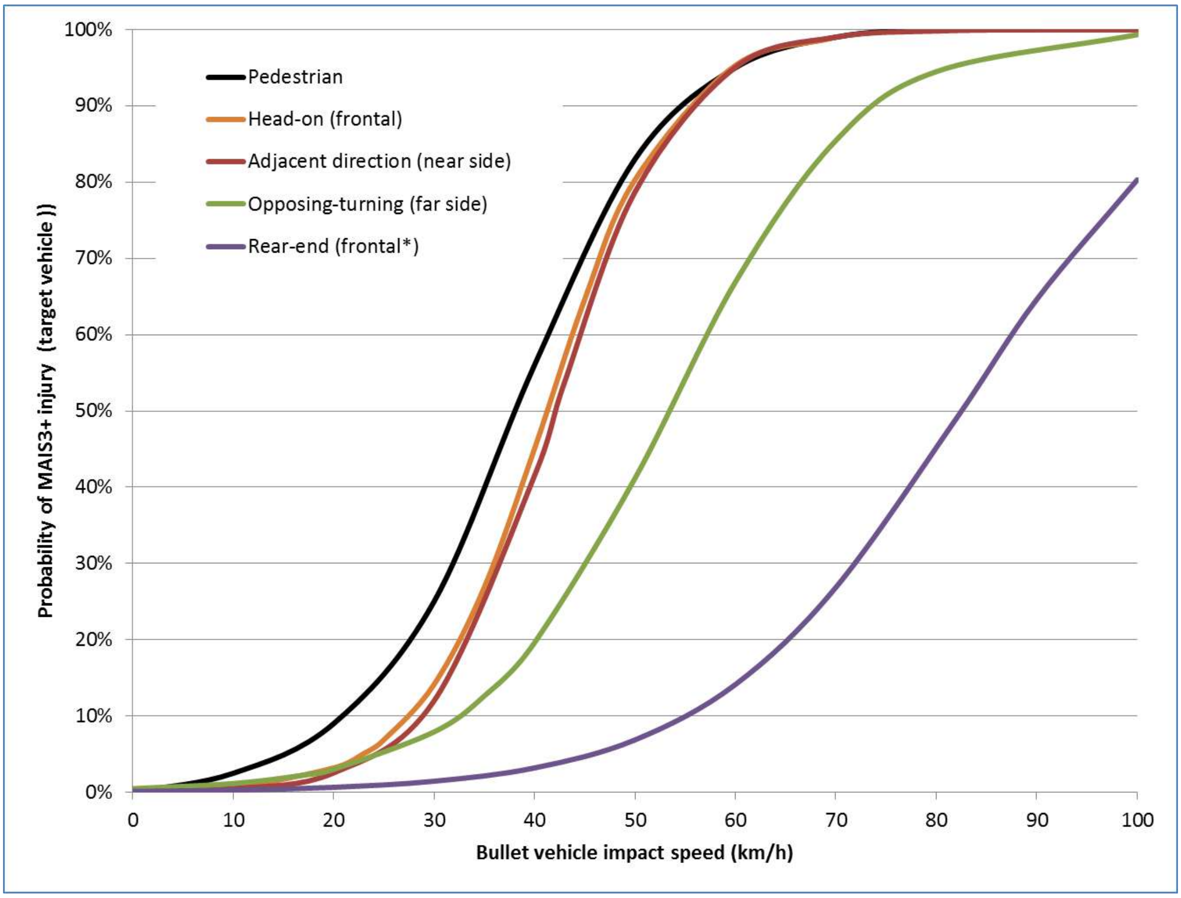
Crash type	Critical impact speed (km/h)
Pedestrian-vehicle	20
Head-on	30

[2] E.g. adjacent direction can occur on far or near side, but it is the latter which is more severe, and was thus used in the relationship.

Adjacent direction	30
Opposing-turning	30*
Rear-end	55

* Depending on the impact angle and the turning vehicle speed, this value may vary.

Figure 4. Proposed model of severe injury probability vs. bullet vehicle impact speeds in different crash types



Source: based on Bahouth et al. (2014), Davis (2001).

Table 2. Assumptions used in Figure 4, and sensitivity of P(MAIS3+) to angle of impact

Crash type	Impact angle (Refer to Figure 3)	Target vehicle speed	Scenario adopted	Pr(MAIS3+) sensitivity to impact angle change ±10°
Pedestrian	NA	NA	Any	Unknown
Head-on	180°	Same as bullet	Frontal	Negligible
Adjacent direction	90°	Same as bullet	Near side	High, ~30% change
Opposing-turning	225°	20 km/h	Far side	Moderate, 15-20% change
Rear-end	0°	0 km/h	Frontal	Nil if the target vehicle is stationary

* General assumptions: baseline severity is a non-injury tow-away event, vehicle occupants were seat-belted, no secondary or rollover collisions, applies to post-2002 vehicle models, front seat occupants only aged 16-55 (Bahouth et al. 2014); inelastic collision (no rebound), equal vehicle mass.

Estimation of critical impact speed for run-off-road crashes into narrow roadside hazards or safety barriers is more complex. Delta-v is not a good predictor of severity which is also affected by the area of impact, the size, mass and rigidity of hit vehicle (Joksch 1993). Hence, no simple impact speed–severity relationship could be found or developed at this time. As an indication, ANCAP uses an impact speed of 29 km/h in its rigid pole impact test which should result in low risk of severe injuries for a five-star vehicle (Australasian New Car Assessment Program 2015). This may act as temporary guidance until a more definitive relationship can be identified or developed for different roadside object types.

Discussion

The curves in Figure 4 shed a new light on the relationship between crash severity and impact speed. Given the clear research references and relevance to both fatal and serious injuries, these new relationships may be more appropriate for use in road design than the Wramborg (2005) curves. Still, they require further research and refinement as outlined below.

The impact speed relationship for opposing-turning crash type is the most complex of those in Figure 4. It is subject to several assumptions which influence the Safe System critical speed value. If a more conservative but less likely scenario is assumed where a passenger is present[3], the critical impact speed is approximately 25 km/h. These considerations were being included in the detailed analysis of designs in the concurrent Austroads project focussing on Safe System intersections.

A major shift in understanding of the impact speed–severity relationship relates to head-on crash type. While Wramborg (2005) suggests this is the most forgiving crash type for fatality, the new evidence indicates the opposite for severe injury. It is possible, that Wramborg’s curve was based on an earlier version of a delta-v relationship. Or perhaps, there is a large disparity between serious and fatal injury impact speed thresholds. It is the large drop in vehicle speed during a head-on crash, a complete stop is assumed, which elevates this crash type’s serious injury risk. Not coincidentally, head-on’s are the second most severe intersection crash types in Victorian data, after pedestrian crashes (Austroads 2013).

The review of other MAIS3+ probability–delta-v relationships from the literature produced varied results, even when similar methods and data sources were used. This raises questions about the absolute accuracy of these relationships. For instance Bahouth et al. (2012) suggest a less harsh set of relationships than Bahouth et al. (2014) or Augenstein et al. (2003a, 2003b). Attempts to contact the authors to discuss these differences were not successful. It is clear that NASS/CDA data selection procedures, crash periods used, and other assumptions would influence the findings. Also, the studies had a specific objective in mind, which was different from this study’s objective. It would be beneficial to have less exclusive relationships, e.g. for all vehicle occupants not just those in the front, and to include all ages of occupants; and developments in vehicle safety over time.

Figure 4 should be used as an indication only. Each curve is conceptually broad and the lines shown are the best estimates only. Due to many assumptions in the preparation of the relationships, the threshold speeds in Table 1 should not be taken as precise values. Each has a broad variance about it, representing the range of circumstances that happen in real life. The small size of the high delta-v collision sample in Bahouth et al. (2014) means the top end of these relationships is subject to a particularly wide standard error and should be not be considered as reliable at high speeds.

The limitation of the age of vehicle occupants to the 15-55 range means the Figure 4 relationships would need to be modified to model outcomes for older or younger road users.

At present, the interaction between vehicles of substantially different mass is to be expected in the system, and should be explored. Future investigations could determine the distribution of vehicle weight ratios in potential conflicts. A more appropriate ratio could be adopted in Equation 1 to derive a more representative version of Figure 4 relationships.

[3] Previous investigations in Jurewicz et al. (2014) showed occupancy rates are low in urban areas ~1.3 persons per vehicle, 1.5 on rural highways and 1.7 on interstate freeways in Victoria.

Davis (2001) used pedestrian crash data from the 1960s and 70s to inform the relationship in Figure 4. Thus this relationship would be ideal for revision using a more recent data.

For these reasons, it would be highly desirable to carry out further research in this area. The first objective would be to redevelop the statistical models for Pr(MAIS3+) vs. delta-v for Australasian policy context, i.e. for different crash types (e.g. adjacent direction), rather than for different impact types (e.g. near-side). Further, more inclusive model assumptions could be tested, e.g. regarding age and vehicle position of occupants, and vehicle age. Local verification of the models could be attempted using Australian and/or New Zealand crash reconstruction data, e.g. by combining CASR and ANSIS in-depth crash data bases if possible. Such relationships would need to be subjected to thorough peer scrutiny and discussion before they could be recommended for consideration in future road safety policies in Australia and New Zealand.

Appropriateness of a 10% MAIS3+ probability threshold as a critical benchmark should be confirmed. This could be done using data from a jurisdiction with current tow-away and casualty crash data. In the interim, rather than adopting an above/below 10% dichotomy, it would be preferable to evaluate and rank alternative design solutions according to their relative alignment with the zero probability of severe injury objective of the Safe System.

It is also clear that Safe System performance of road infrastructure cannot be wholly achieved by controlling impact speeds and angles (i.e. geometry and layout), especially where high speeds are desired to meet the mobility function. This means that more weight should be placed on minimising probability of road user conflicts. Road user separation, minimisation of number of conflict points, and greater management of road user movements can all be used to provide solutions supporting the Safe System vision.

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Behind the Wheel: a randomised controlled trial evaluating a safe transport program for older drivers

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Extended Abstract

Introduction:

Age-related changes to vision (Rubin et al., 2007), visual attention (Ball, Owsley, Sloane, Roenker, & Bruni, 1993), cognitive and physical function (Anstey, Wood, Lord, & Walker, 2005) can negatively impact on driving ability and increase crash risk. Though self-regulation of driving is common (Molnar & Eby, 2008) and a promising strategy to promote safety (Classen et al., 2007), surveys find older drivers tend not to plan for driving cessation and are not familiar with alternative transport (Kostyniuk & Molnar, 2008).

The authors' hypothesised that an education based program can change actual driving practices and engage older drivers in planning for retirement from driving. Our aim was therefore to ascertain whether a one-on-one safe-transport program can change driving exposure while maintaining community participation in a group of older drivers using a randomised controlled trial.

Methods:

We evaluated an adapted version of the KEYS® program (Stalvey & Owsley, 2003), in a randomised controlled trial involving 380 drivers aged 75 years and older, residing in the suburban outskirts of Sydney.

Participants

Volunteers aged 75 years or older were invited to participate through various media including newspaper advertisements, public meetings and letters of invitation sent by a motoring organisation. Participants were required to hold a valid drivers' license, speak English, and be the primary driver of their vehicle. Drivers who shared a vehicle or scored more than two errors on the Short Portable Mental Status Questionnaire were excluded from the study. We recruited 380 drivers (230 or 61% men, 150 women) and successfully installed in-vehicle monitoring devices in 362/380 (95%) vehicles. After baseline assessment, participants were randomised into the intervention or control group using remote login to an in-built randomisation feature of the study database. 190/380 (50%) participants were allocated to each group, and 366/380 (96%) completed the 12-month study.

Program

The intervention group received an education-based safe-transport program delivered in two sessions, one month apart. The safe transport program was based on the Knowledge Enhances Your Safety (KEYS) program, which was adapted for the Australian context. The program aimed to assist older drivers make safe and informed decisions about their driving exposure, while maintaining community participation, and to plan for retirement from driving. The control group received no intervention.

Setting

Assessment data was collected and education delivered in participants' homes located in the suburban outskirts of northwest Sydney.

Main outcome measure

The main outcomes were distance driven (km) per week over 12-months measured by in-vehicle monitoring devices hardwired into participants' vehicles and community participation measured by the Keele Assessment of Participation. In-vehicle monitoring devices included a global positioning system (GPS) with data logger which captured time-stamped second-by-second GPS location during vehicle operation. Secondary outcomes included the stage of behaviour change with regards to self-regulation of driving and uptake of alternative transport at 12-months. Data were analysed using intention-to-treat. Generalised estimating equations modelled the impact of the safe-transport program on driving exposure, adjusting for repeated, weekly measures over 12-months. Ordinal regression was used to analyse differences in behaviour profiles between groups. Data were analysed by researchers blinded to group allocation. Three subgroup analyses based on sex, age and function were performed on the main outcome of distance driven. Function was assessed using DriveSafe, a computerised assessment of visual attention to the driving environment.

Results

The mean age of participants was 80±4 years. On average, participants drove 140±167km per week. The safe-transport program was delivered as intended to 183/190 (96%) of drivers in the intervention group.

While there was no significant difference in distance driven per week over 12-months (between-group difference: -5.5km, p=0.57, 95% CI:-24.5 to 13.5km), participants in the intervention group were more engaged in self-regulatory driving practices than those in the control group (OR:1.6, p=0.02, 95% CI:1.1-2.3). These results are shown in Table 1.

Table 1. Trial results

	n	Intervention mean±SD	n	Control mean±SD	Difference estimate (95%CI)	p value
Primary Outcomes						
Total distance driven per week (km)	172	137.2±171.5	175	143.2±163.7	-5.5 (-24.5 to 13.5)	0.57
Keele Assessment of Participation (score)	183	1.3 (1.0-1.7)	182	1.4 (1.1-1.8)	-0.1 (-0.6 to 0.3)	0.59
Secondary outcomes						
Behaviour profile, n (%)	183	92 (50.3) 36 (19.7) 31 (16.9) 24 (13.1)	182	108 (59.3) 39 (21.4) 24 (13.2) 11 (6.0)	Odds ratio 1.8 (1.2 to 2.6)	0.006
Use of alternative transport (trips)	183	4.8 (3.7 to 5.8)	182	4.7 (3.6 to 5.7)	0.1 (-1.4 to 1.6)	0.90

At 12-months there was similar use of alternative transport, with participants taking 5 trips on average in the previous month (between-group difference: 0.1, p=0.90, 95% CI:-1.4 to 1.6). The interactive term for subgroup analyses did not reach significance. Importantly, there was no difference in community participation between those who received education and those who did not (between-group difference: -0.1, p=0.59, 95%CI:-0.6 to 0.3).

Discussion

This research found an individualized, safe transport program can engage older drivers in the process of self-regulation. This finding is in agreement with the original evaluation of the KEYS program which found the program promoted self-regulation amongst older licensed drivers who were visually impaired and crash involved in the previous year (Owsley, Stalvey, & Phillips, 2003). However, using objective measurement of driving the analysis, we did not find a significant reduction in weekly mileage during a 12 month period.

This trial shows that an individualised safe-transport program can promote behaviour change, although did not translate into a significant difference in weekly mileage after 12-months. Though we did follow the study participants for 12 months, longer follow-up extending for a number of years may be required to account for gradual age-related changes and implementation of self-regulatory driving practices over time.

Trial registration: Australian New Zealand Clinical Trials Registry ACTRN12612000543886

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Traffic behaviour and compliance with the law in low and middle income countries: are we observing "pragmatic driving"?

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Abstract

A common theme in many accounts of road safety and road use in low and middle income countries is a widespread lack of compliance with traffic laws and related legislation. A key element of the success of road crash prevention strategies in high income countries has been the achievement of safer road user behaviour through compliance with traffic laws. Deterrence-based approaches such as speed cameras and random breath testing, which rely on drivers making an assessment that they are likely to be caught if they offend, have been very effective in this regard. However, the long term success of (for example) drink driving legislation has been supported by drivers adopting a moral approach to compliance rather than relying solely on the intensity of police operations. For low and middle income countries such morally based compliance is important, since levels of police resourcing are typically much lower than in Western countries. In the absence of morally based compliance, it is arguable that the patterns of behaviours observed in low and middle income countries can be described as "pragmatic driving": compliance only when there is a high chance of being detected and fined, or where a crash might occur. The potential characteristics of pragmatic driving in the macro-, meso- and micro-context of driving and the enforcement approach that could address it are outlined, with reference to the limited existing information available.

Introduction

The statistics on global road fatalities are now well known and frequently cited – more than 1.2 million people are killed as a result of road traffic injuries each year and tens of millions experience non-fatal injuries that disable them temporarily or permanently (WHO, 2013a). Although high income countries (HICs) including Australia account for almost half of the world's registered motor vehicles, about 90% of road fatalities occur in Low and Middle Income Countries (LMICs) (Wesson et al, 2014). In East Asia and the Pacific, road traffic injury ranked third in causes of loss of disability adjusted life years in 2010, compared with 10th globally, and total road fatalities in the region have increased by 50% since 1990 (IHME and HDN, 2013). These crashes have a high economic cost (Wesson et al, 2014) and a significant impact on development (Bliss and Breen, 2012), which reduces the effectiveness of international aid across all of the Millennium Development Goals (Ericson and Kim, 2011).

Road infrastructure in LMICs has been improving, and Australian aid has continued to make a significant contribution to this. However, behaviour of road users in LMICs remains a major problem, a common observation being that it is chaotic, or lawless (Chalya et al, 2012; Gostin and Friedman, 2013; Jain et al, 2012; Kolnberger, 2012). This is to some extent an exaggeration, because drivers and motorcyclists try to avoid colliding with each other or with pedestrians, i.e. it is not a "demolition derby". However it is true that illegal and unsafe road user behaviours are widespread, e.g. not wearing a motorcycle helmet, failing to comply with traffic signals/signs, and speeding. This is a problem of compliance with safety-related rules. Research in LMICs indicates that in most cases, non-compliant drivers and riders know what they should do, but do not do it (Isoba, 2002). As a consequence there is an emphasis on a multifaceted approach that involves: "adopt(ion) and implement(ation of) national road safety legislation and regulations on the major risk factors, and improve implementation through social marketing campaigns and consistent and sustained enforcement activities" (UN General Assembly Resolution 66/260(6), cited by WHO, 2013b). Given that legislation and social marketing by themselves have limited impact, police enforcement plays a crucial role in achieving compliance with road safety legislation (Bates et al, 2012).

There is a considerable body of literature on the relationship between police enforcement and compliance with the law, including a substantial literature devoted to enforcement of traffic law (Davey and Freeman, 2011). The primary concept is that of deterrence of offending, often broken down into specific deterrence (the person caught and punished is deterred from reoffending) and general deterrence (people in general are deterred from offending, without having been caught) (Davey and Freeman, 2011). In classical deterrence theory the main factors that contribute to higher deterrence are a high perceived risk of being detected, a high perceived severity of the punishment, a high perceived certainty that the punishment will be administered if caught, and a perception that the punishment will administered swiftly (Fleiter et al, 2013). In recent research (Scott-Parker et al, 2013) the role of punishment avoidance has been investigated – committing an offence and not being detected – and further theoretical elaboration of deterrence and punishment in relation to road use behaviour has been undertaken (Fleiter et al, 2013).

Compliance through deterrence is supplemented (and ideally replaced in the long run) by voluntary compliance based on *moral adherence to the law*, either because the law is considered to be morally justified, or because it is considered morally right to comply with authority even if the law is contestable (Davey and Freeman, 2011). This paper proposes that a driver strategy that explains a lack of voluntary compliance is *pragmatic driving* where compliance only occurs in response to the deterrence variables and anticipated collision risk, and where no moral component exists. It is further argued that pragmatic driving is common in LMICs and presents significant challenges to the use of enforcement as a means of achieving voluntary compliance, and some suggestions are made for addressing these challenges.

What is "pragmatic driving"?

Dictionary definitions of "pragmatic" and "pragmatism" refer to an emphasis on the practical consequences of actions. Here, the following is proposed:

> ***Pragmatic driving*** *describes driving behaviours that achieve personal mobility aims while optimising perceived safety and enforcement risks, regardless of the legality of the behaviours involved*.

Essentially, drivers are aiming to reach a destination with a minimum of delay, taking into account the possibility of a collision and likelihood of being detected committing an offence. The legality of their behaviour is only relevant if enforcement is a possibility.

Figure 1 presents a more comprehensive approach that describes the factors that influence compliant or pragmatic driving, and makes an important distinction between macro-, meso- and micro-contexts.

Macro-context: comprises enduring factors that influence a driver's behaviour across trips. Some drivers tend to comply with the law, either because they see it as morally justified, or because they believe it is important to comply with laws even if they do not necessarily agree with them. Tapp et al (2015) identify these two groups in their survey of British drivers' support for and compliance with low residential speed limits. Some drivers will generally disregard the law and therefore display pragmatic driving across most circumstances. Personality traits and dispositions (e.g. intention to comply or offend, optimism bias) operate at this level also.

Meso-context: comprises factors that influence driver behaviour during a particular trip, and therefore moderate the influence of macro-context factors. An import influence is the degree of time pressure, while fatigue and impairment by alcohol or drugs will also affect behaviour during the trip. The influence of passengers during a trip is well documented (e.g. Scott-Parker at al, 2009) and has been categorised here as impression management, which also includes managing impressions presented to the public while driving an identifiable company car; this would also apply to fleet vehicles where driver behaviour is recorded and/or monitored. The general behaviour of other drivers during the trip would also have a social contagion effect (Tapp et al, 2015). These trip-based factors could influence pragmatic driving among drivers who are otherwise compliant, e.g. time pressure leads to speeding, while keeping watch for police enforcement.

Micro-context: comprises factors in the immediate traffic situation. An important factor is the expected behaviour of other drivers, i.e. whether it is anticipated that they will comply with the laws or not, whether they will act selfishly or employ courtesy, etc (Lennon and King, 2015). This sets up something analogous to a "prisoner's dilemma" scenario which lends itself to utility-based decision-making. Drivers who comply with the law might be disadvantaged by time delay in both absolute terms (actual delay) and relative to other drivers who do not comply. However, by failing to comply there is a crash risk and a possibility that the offence will be detected and punished.

It is hypothesised that pragmatic driving would be most commonly observed in the micro-context, since there will be situational factors that will influence drivers who would normally comply in general (macro-context) and have been compliant during the trip (meso-context) to take a more pragmatic approach in a specific traffic situation if compliance is too costly. For example, if a traffic light will not respond to vehicle presence, even drivers who are highly compliant are likely (once they have waited long enough) to go through the red when they judge it safe enough to do so.

Figure 1. Macro-, meso- and micro-context factors influencing compliant vs. pragmatic driving

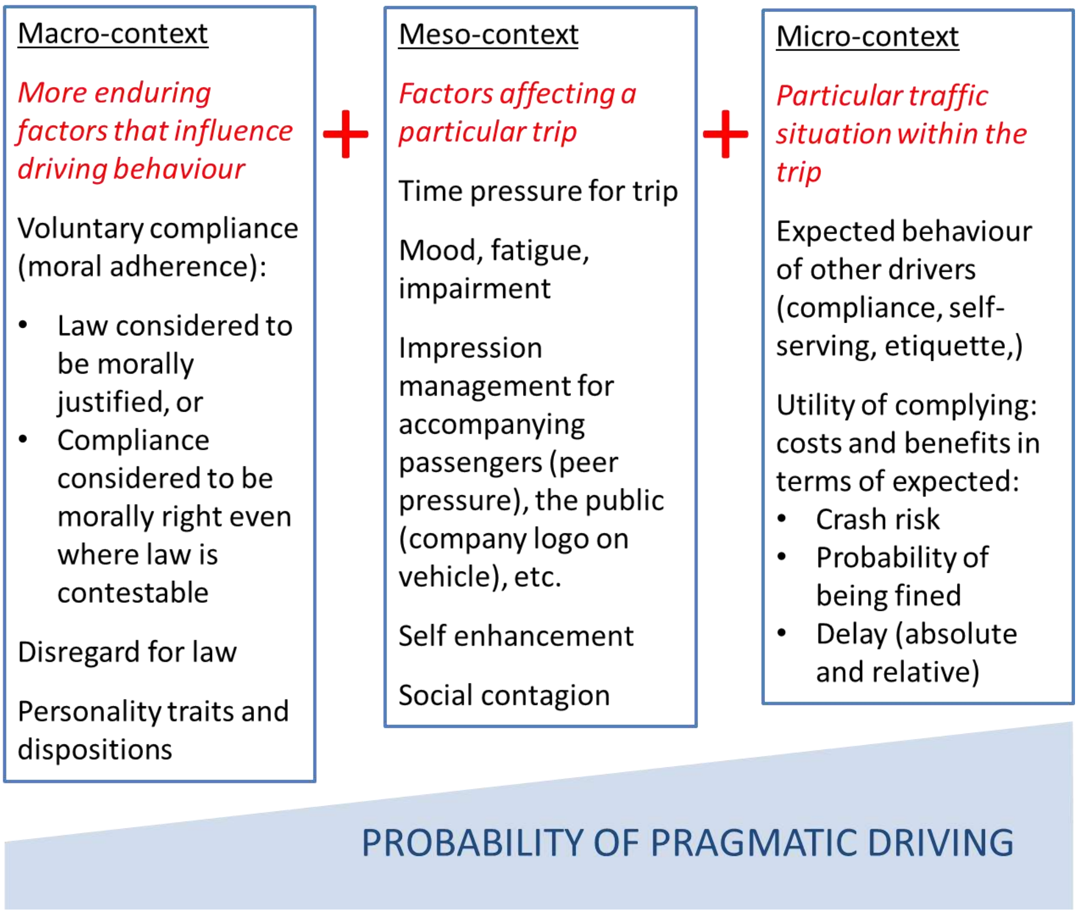


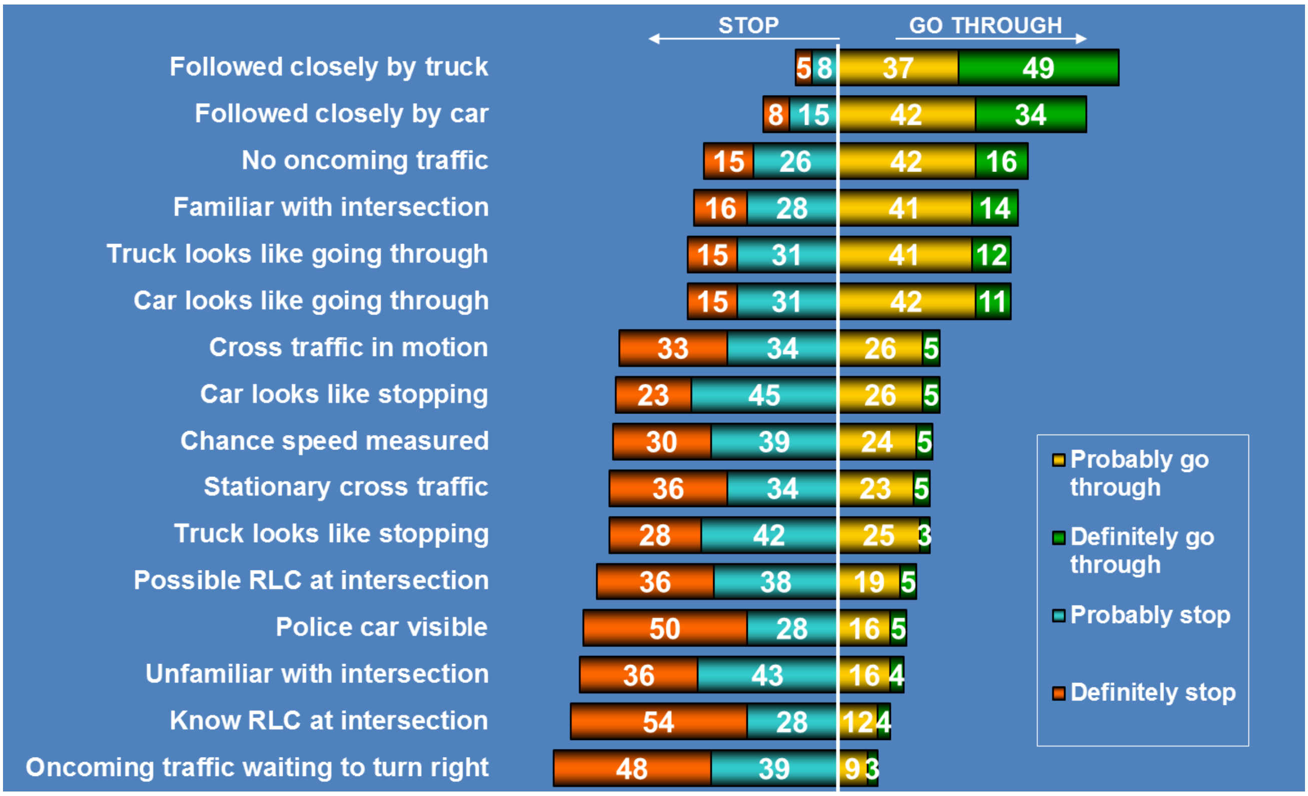
Illustration of micro-context factors involved in pragmatic driving

Examples of micro-context factors involved in pragmatic driving can be identified in an unpublished study of driver behaviour approaching signalised intersections in Queensland (AC Nielsen, 2002a,b,c). It should be noted that the situation examined was not one of noncompliance with the law, however the factors influencing behaviour are expected to be the same. The study was commissioned by Queensland Transport (who have given permission for its use) to understand awareness and behaviours in relation to red light cameras. The author designed the questionnaire and established the methodology in consultation with AC Nielsen: a random telephone survey with 504 residents (304 in Brisbane, 100 each in Toowoomba and Townsville) aged 17 or above and holding a current Queensland drivers licence. They were given the following scenario:

> "I'd like you to imagine that you're driving a car, and you're approaching an intersection with traffic lights. The lights change from green to yellow just as you get close. You would have to brake quite hard to stop, but if you go through, the light might turn red before you reach the other side. As you might know, it would not be illegal if you did go through. In this kind of situation there are many things that might make you more likely to stop, or more likely to keep going. I'll mention some of these, and after each one I'd like you to tell me what you think you would do. There is no right or wrong answer, it's just how you think you would react."

Respondents were then presented with a series of 16 scenarios with different characteristics, with the order of presentation changed from respondent to respondent: no oncoming traffic; oncoming traffic waiting to turn right; stationary cross traffic waiting at the lights; no waiting cross traffic, but traffic in motion approaching the lights; truck/car is following very closely; truck/car is alongside and likely to go through/stop; definitely/possibly a red light camera at the intersection; chance speed could be measured; police car visible; familiar/unfamiliar with intersection and sequence of lights. The results are presented in Figure 2.

Figure 2. Percentage of drivers who would stop or proceed upon a yellow light, by scenario (Source: AC Nielsen 2002a, slide 20)



Respondents were most likely to stop when there was a collision risk with oncoming traffic waiting to turn right (87% definitely/probably stop), stationary cross traffic that could start when the light changes (70%) and cross traffic heading towards the lights (67%). When there was no oncoming traffic, only 41% would definitely/probably stop. When a collision from behind was possible, respondents were most likely to go through, with only 13% and 23% definitely/probably stopping if followed closely by a truck or car respectively

The influence of deterrence can be seen in the scenarios where drivers know there is a red light camera at the intersection (82% definitely/probably stop), a visible police car (78%), a possible red light camera (72%) or a chance their speed could be measured (69%). Interestingly, these figures are of the same order as the figures for the scenarios where going through the yellow presents a collision risk. The presence of a known red light camera or a visible police car also changes the balance within those who would "definitely/probably stop" in favour of "definitely stop". Familiarity with the intersection is important, with more willingness to stop when the intersection is unfamiliar (79% definitely/probably) than when it is familiar (44%).

An interesting influence was the perceived behaviour of vehicles travelling alongside the driver, where drivers were less likely to report definitely/probably stopping when alongside a truck (46%) or car (46%) they thought was likely not to stop, compared with travelling alongside a truck (70%) or car (68%) they thought was likely to stop. It is not clear whether this is an assumption that the other driver has better information on which to make the decision, an assessment of physical protection if there is conflict with traffic in the intersection (though the truck/car weight differential might have been expected to have an influence), a simple reliance on "safety in numbers" or the outcome of a form of social pressure.

The results show that driver decisions in the micro-context, although they take place rapidly, involve assessment of other drivers' likely behaviour (will turn/go though), the risk of collision, the likelihood of enforcement and familiarity (which is related to prediction of the behaviour of other drivers and collision risk, e.g. when the cross traffic will get a green light). It is worth noting that in every scenario there was a proportion of drivers who would probably/definitely not stop, regardless of the possible contingencies.

Pragmatic driving in LMICs

Familiar scenarios in LMICs include crowded roads where lanes are ignored, roundabouts where everybody enters and then slowly negotiates a way through, red lights that are violated on almost every change of lights, drivers going the wrong way down one-way streets, and motorcyclists driving against the traffic. However, despite this familiarity there is little available research that lends itself to a description of pragmatic driving.

In one exception to this lack of research, Kolnberger (2012) refers to Phnom Penh as being distinguished by "the seemingly chaotic traffic or the anarchic character of driving; a mixture of social conformity and chaotic individualism" (Kolnberger, 2012:5). His analysis of traffic in the city is based on theorising the transition from the road as shared unregulated public space to a regulated area with controlled access, and assessing the difficult shift from what was essentially pragmatic driving by default, to an uneasy mix of continued pragmatic driving (as a matter of custom and choice) and compliant driving, with increased legislation and enforcement.

There is an overlap between pragmatic driving and congestion, such that research which is focused on congestion in LMICs sometimes paints a picture that is clearly recognisable as pragmatic driving:

> "The impact of poor lane discipline, especially at traffic junctions, deteriorates the already overcrowded junction situation. Furthermore, drivers frequently jump red lights and block the intersection, causing further traffic congestion. These problems are compounded by the fact that traffic law enforcement is poor, thereby providing no incentive for drivers to follow the rules." (Jain et al, 2012:2)

In addition, the author has a longstanding interest in road safety in LMICs and has made observations in several countries that are consistent with those above. Some examples follow:

> "I was trying to see how people negotiated the intersection [in Khon Kaen, Thailand]. If a reasonable flow had built up in one direction it would continue, until either a gap appeared or another vehicle (from another approach) has edged sufficiently into the stream to cause it to slow, eventually edging enough to make a space. Motorcyclists used cars, buses and trucks as cover if necessary, otherwise they had to make their own way through. Turning left is easy and seems not to consider through traffic…. Motorcycles in particular look for opportunities to flow through in various innovative ways, even turning right into the wrong side of the road, negotiating through oncoming traffic." (King, 2005, Appendix 3.5:22)

> "One of the differences between Hanoi and Australia with respect to road use behaviour is the blurring of boundaries and limits, and the interpermeability of territory. Unlike Australia, where road use for most classes of road user is strictly delimited (in practice as well as in law), this is not the case in Vietnam – motorbikes ride onto the footpaths, where pedestrians don't have automatic right of way, pedestrians walk on the road (often through lack of choice), vehicles frequently use the "wrong" side of the road when driving, do not stop at traffic lights, begin a left turn from the right hand side of the traffic flow, etc." (Excerpt from observation note by author)

> "One of the characteristics that marks the traffic here [Hanoi], especially in merging, is that the riders of motorcycles and bicycles (and possibly car drivers) seem to ride into an intersection or stream of traffic paying no attention at all to the traffic there. This is most

obvious when a motorcyclists turns into the traffic from a side street – there is no movement of the head to look at the traffic, possibly because this concedes some kind of advantage to the traffic. Similarly, road users rarely respond to horn blowing with any indication that they have heard it, apart from perhaps moving out of the way. If they can't move out of the way, they just seem to ignore it. Presumably they have registered that there is a vehicle there, but it is far from clear to me whether this is considered important at all." (King, 2005, Appendix 3.5:22)

"….making eye contact with drivers or motorcycle riders [in Bangkok] doesn't do any good – it just lets them know that you've seen them, so they feel confident about continuing without a change of speed. So you have to pick a gap and begin walking – warily, but smoothly. Because of all the motorcycles and *song taews* [public transport – a one-tonne light truck with a canopied rear lined with bench seats] diving in and out, there are no orderly lanes of traffic, unlike Australia, so a temporary gap is still chancy. If you walk slowly but continuously, both the oncoming straight and weaving traffic can anticipate you, but you have to keep an eye on what's coming behind the oncoming vehicles as well. If people do stop for you, it's usually not because they're doing you a favour, but because they see it as their duty not to run you down." (King, 2005, Appendix 3.5:20)

"At intersections [in Beijing] it is much more chaotic as drivers and cyclists play a restrained form of chicken, taxis blowing their horns in warning. At times the taxis went through red lights, particularly when turning right (left in Australia), and cyclists were even more likely to ignore the red light and negotiate a way through. Pedestrians also did this, even on marked pedestrian crossings, which appear to be ignored by drivers and used by pedestrians simply because it's a convenient place to cross. At one time, when turning right under an underpass, the taxi had opposing traffic (also turning) going by on both sides of him." (Excerpt from observation note by author)

Further similar observations by the author have been made in these countries as well as in Cambodia, Ethiopia, India, Indonesia and the Philippines. The concept of pragmatic driving emerged in part from a motivation to make sense of the traffic behaviour observed across these different countries.

Implications for achieving voluntary compliance

The evidence outlined above presents a picture consistent with the thesis that pragmatic driving is common in LMICs, although as yet (for obvious reasons) there is a lack of systematic and focused research. For example, it would be possible to articulate the relationships between the factors in Figure 1 in a more detailed way, including feedback loops between the experience of non-compliance by other drivers in the micro-context and individual drivers' commitment to compliance in the macro-context. This requires applied traffic psychology research which takes into account the difference in social and cultural context (King, 2005). However, even in the absence of such research information, it is important to consider the implications of pragmatic driving for the achievement of compliance with traffic law in LMICs, as this could point to promising interventions.

Returning to Figure 1, it can be seen that an important factor in the micro-context is the driver's expectation of the behaviour of other drivers. When a roundabout needs to be negotiated, if drivers expect that other drivers will simply enter when they can without heed for the legal right of way, it is logical to do the same and therefore avoid excessive delay. Even drivers who believe that compliance is morally right have been shown to "relax" their compliance in response to situational factors (Tapp et al, 2015). Therefore it appears that the objective of interventions intended to reducing pragmatic driving should be to change expectations of other drivers' behaviour, which in effect means changing the actual behaviours, i.e. achieving compliance.

The evidence available from studies that demonstrate an improvement in long term compliance with traffic law generally shows that sustained enforcement is required (Fell et al, 2008; Terer and Brown, 2014). Unfortunately, LMICs lack the police resources to achieve such a sustained effort (Forjuoh, 2003). It is common for traffic police to spend much of their on-road time directing traffic to help ease congestion, i.e. in a situation where detaining drivers to issue a fine will make the problem worse rather than better. As a result of the inability to sustain enforcement levels at anywhere near the levels employed in Australia (e.g. see Ferris et al, 2013 re intensity of random breath testing), offences such as drink driving and speeding remain at high levels in LMICs (e.g. Damsere-Derry et al, 2015; Jia et al, 2015).

Even in HICs sustained enforcement has been selective in terms of the particular laws enforced. In Australia the first documented successes were in the area of drink driving, with sustained high levels of random breath testing (Bates et al, 2012). Speed has been a more important focus in the past two decades (Bates et al, 2012), though without sacrificing the intensity of random breath testing. Notably, enforcement intensity for both these offences relies on a combination of technology and the use of techniques that have been developed and evaluated over a period of time, as well as the commitment of personnel and funding. LMICs face challenges in all of these areas of capacity. On the other hand Vietnam has successfully achieved a substantial change in motorcycle helmet wearing through legislation and enforcement (Passmore et al, 2010) that has not required sophisticated technologies or techniques.

In terms of Figure 1, the "flagship" enforcement approaches to drink driving, speeding and helmet wearing operate on the meso-context rather than the micro-context: drink driving and non-wearing of helmets operate for the entire trip, and although speeding is ephemeral, it is common for drivers to adopt illegal speeds for a number of sectors of a trip rather than just one or two. In contrast, pragmatic driving is most common in the micro-context, i.e. a specific situation at a specific location. Across the road system there are so many such locations that the possible number of enforcement locations is much greater than those used for drink driving and speeding enforcement. This multiplies the challenges for LMICs.

Furthermore, while enforcement approaches for drink driving, speeding and helmet wearing allow police to focus on a single high profile behaviours for which individual drivers can readily be held responsible, pragmatic driving involves clusters of non-compliant behaviours that are a product of interactions between a number of drivers. In addition, these non-compliant behaviours can be perceived by all the drivers concerned as justifiable for the very reason that they are pragmatic – they enable drivers to achieve their mobility objectives better in the given situation. While speeding also has a mobility rationale, it involves a risk to other drivers, as does drink driving, while not wearing a helmet has no mobility benefit as well as presenting an individual risk.

Pragmatic driving therefore presents a complex enforcement problem: limited police resources, and a diffuse non-compliance problem that is spread across the transport system, and involves cooperation between numerous drivers for a perceived benefit. A possible approach which (to the author's knowledge) has not been systematically applied and evaluated would be to selectively target particular locations with supporting publicity about both the correct way to drive at that location and the fact that enforcement will be applied there. The locations and road rules to be enforced would need careful selection to ensure that a shift to compliant behaviour would not exacerbate congestion. With a sustained, localised effort, drivers would ideally develop experience with the way the micro-context operates when all drivers comply with the traffic laws, which would enable the enforcement approach to be shifted to other locations. This is based on an assumption about the generalisability of compliant behaviour which requires testing. An evaluation would also be required to establish the level and duration of sustained enforcement required; positive or negative impacts on mobility; the degree of recidivism by drivers when the enforcement is shifted elsewhere and the related benefits of "top-up" enforcement; and changes in intention to comply with the law among drivers. If the impact on mobility is positive, this could be used to support publicity promoting adherence to the law, as already occurs in relation to speeding and mobility in Australia (e.g. RACQ, n.d.).

Conclusion

Lack of compliance with traffic law is common in LMICs. It is proposed that such non-compliance takes the form of pragmatic driving, defined as driving behaviours that achieve personal mobility aims while optimising perceived safety and enforcement risks, regardless of the legality of the behaviours involved. A model that specifies a macro-, meso- and micro-context for driving behaviour is also proposed, and postulates that compliance with the law is mostly an influencing factor at the macro-context level, whereas pragmatic driving is mostly a product of driver interactions in the micro-context where intention to comply is frequently overridden by pragmatic considerations related to mobility. Research is needed to confirm this account and to enable the further elaboration of the model, however some of the implications for practice can be drawn out. The difference between this pattern of non-compliance and traditional enforcement targets such as drink driving, speeding and helmet wearing presents a number of challenges to police in LMICs, which are exacerbated by their lack of resources relative to HICs. It is hypothesised that a promising approach is sustained, localised enforcement with supporting publicity, with evaluation of the resource needs, maintenance of impact and generalisability of results.

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Journey Optimisation by Safest Route

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Abstract

Efficient routing of private and commercial vehicles is valued for saving travel time and reducing vehicle running costs. Employers must also consider the safety of their staff while on the road, and many implement policies that support safe driver behaviours and the use of safe vehicles. To date there has been little research into the integration of both routing and safety – allowing road users to choose the safest, in addition to the shortest or quickest routes.

This paper outlines a research project, undertaken as part of a Callaghan Innovation Student Experience Grant, which investigated how road risk assessment methodologies can be incorporated into a vehicle routing model. Two methodologies for calculating, predicting and quantifying crashes and road safety were examined and tested for the Greater Auckland Region: predictive crash models from the NZ Transport Agency's Economic Evaluation Manual, and reactive crash models based on the Urban KiwiRAP risk assessment methodology.

The project was developed using Geographical Information Systems (GIS), specifically ArcGIS Network Analyst. The output of the trial was an interactive website that allows for users to choose and weight three routing variables: travel time, distance and safety. The route that best meets the chosen priorities is then calculated and displayed on screen.

This project demonstrates potential for safety-based vehicle routing and supports a safe system approach to managing the road safety risk associated with work-related driving. The next step is to explore the commercial opportunities from this research, including partnerships with interested public bodies and commercial vehicle routing services.

Introduction

Vehicle routing is a complex process that is used by businesses and individuals to optimise travel times and reduce vehicle running costs. Optimal vehicle routing is typically undertaken using applications which apply variables such as distance and historic and real-time travel time data to calculate the most efficient route between a defined origin and destination. Currently there are no known vehicle routing services that explicitly incorporate safety variables into vehicle routing.

There is a broad application for routing based on safety. Many companies require routing as part of their day-to-day business operations. With increasing dependence on fast, reliable and safe transport, the idea of taking safety into account would be of interest to companies looking to reduce risk, whilst minimising distance and time costs. Industries and businesses that are reliant on driving (such as logistics and distribution, tradespeople and taxi drivers) could all benefit from a routing system designed to inform them about the relative risk of different route options whilst still supporting efficient business practices. By incorporating safety into distance and time based route calculations, employers can also meet their workplace health and safety obligations.

As part of a Callaghan Innovation Student Experience Grant[1], a research project was completed that explored the feasibility of incorporating safety data into a vehicle routing network. The primary

[1] Callaghan Innovation is a New Zealand Crown Entity established to support the commercialisation of innovation in New Zealand businesses. The Callaghan Innovation Student Experience Grant is a paid R&D internship that provides work experience for students.

output of this research is an interactive website that demonstrates the feasibility of integrating safety metrics into vehicle routing. The website allows users to specify how they would like their route to be calculated by rating the relative importance of safety, distance and travel time. The result is then displayed, along with the shortest and fastest routes; allowing for a visual comparison of options. The methods used in the application have the ability to be scaled and implemented into existing routing applications.

The research also supports the safe system philosophy and the New Zealand's Safer Journeys vision for a 'safe road network increasingly free of death and serious injury' (Ministry of Transport, 2010). The application raises awareness of road safety and empowers road users to make smarter decisions about how they use the road network.

Models of road risk

To calculate the relative risk of travelling a particular route, this risk must be quantified and aggregated across every section of road travelled. The research project investigated two methods of quantifying road safety risk. The first method is a predictive risk assessment from the Economic Evaluation Manual (EEM), which includes procedures to calculate the safety benefits and costs of transport projects (New Zealand Transport Agency, 2013). This risk assessment does not take into account historic crash data, but instead relies on regression algorithms that explain crash performance based on physical and operational variables, such as intersection form and traffic volumes. Whilst the algorithms have been developed by correlating specific features and characteristics with known crash performance, the application of the EEM procedure generates expected injury crash rates that are predictive in nature.

The second method tested is the Urban KiwiRAP methodology, which relies on crash history to predict the likelihood of future deaths and serious injuries if current crash trends continue (Brodie et al., 2013). Urban KiwiRAP calculates two risk metrics that can be used to quantify road safety risk:

- **Collective Risk** is measured as the estimated number of deaths and serious injuries based on severity indices associated with historic crash data.
- **Personal Risk** is the risk of death or serious injuries per 100 million vehicle kilometres travelled.

Urban KiwiRAP is a reactive approach to risk assessment. Waibl, Tate, & Brodie (2012) discuss the shortfalls of such a method. For this research, the Personal Risk metric was used as it provides a risk relative to an individual and not the absolute, or Collective Risk of each route.

Table 1 outlines the two methods tested, their required inputs and calculations. It shows how the two methods vary and indicates why there may be differences in the results.

Table 1. Outline of the inputs and calculations required for each of the methods.

Method	**Inputs**	**Calculation**
Economic Evaluation Manual	• Annual average daily traffic (AADT) • Length of the link • Two model parameters based on the road type	Using regression, a formula is populated with the appropriate values and the resulting metric is calculated.
Urban KiwiRAP	• Number of lanes • Annual average daily traffic (AADT) • Number of injury crashes (over five years) • Speed environment (urban/rural)	A model assigns crashes to links and based on a range of input criteria and the type of crash, calculate the Collective and

	• Road hierarchy	Personal Risks.

KiwiRAP star rating was considered as an alternative method for quantifying road safety risk along corridors, however at the time of the research, star rating had only been undertaken for the New Zealand State Highway network. While further star rating assessment is currently being undertaken for selected roads in some of New Zealand's main cities, the lack of risk assessment coverage makes it difficult to quantify risk across an entire road network.

Methodology

A Geographical Information System (GIS), ArcGIS 10.2, was used to view, manage and work with the data. The GIS contains a range of tools that enabled analysis and development of the spatial data. Once the necessary data had been acquired, development of a vehicle routing network and comparison of the two safety metrics was undertaken. The project was concluded with the development of an interactive website.

The Auckland region New Zealand was used as the study area for this project. Auckland was one of the first regions in New Zealand to have Urban KiwiRAP safety metrics calculated (Figure 1) and provided a mix of urban and rural road environments to test the routing model. There was also sufficient suitable data available for calculating the metrics using the EEM methods as well as a complete set of road centrelines.

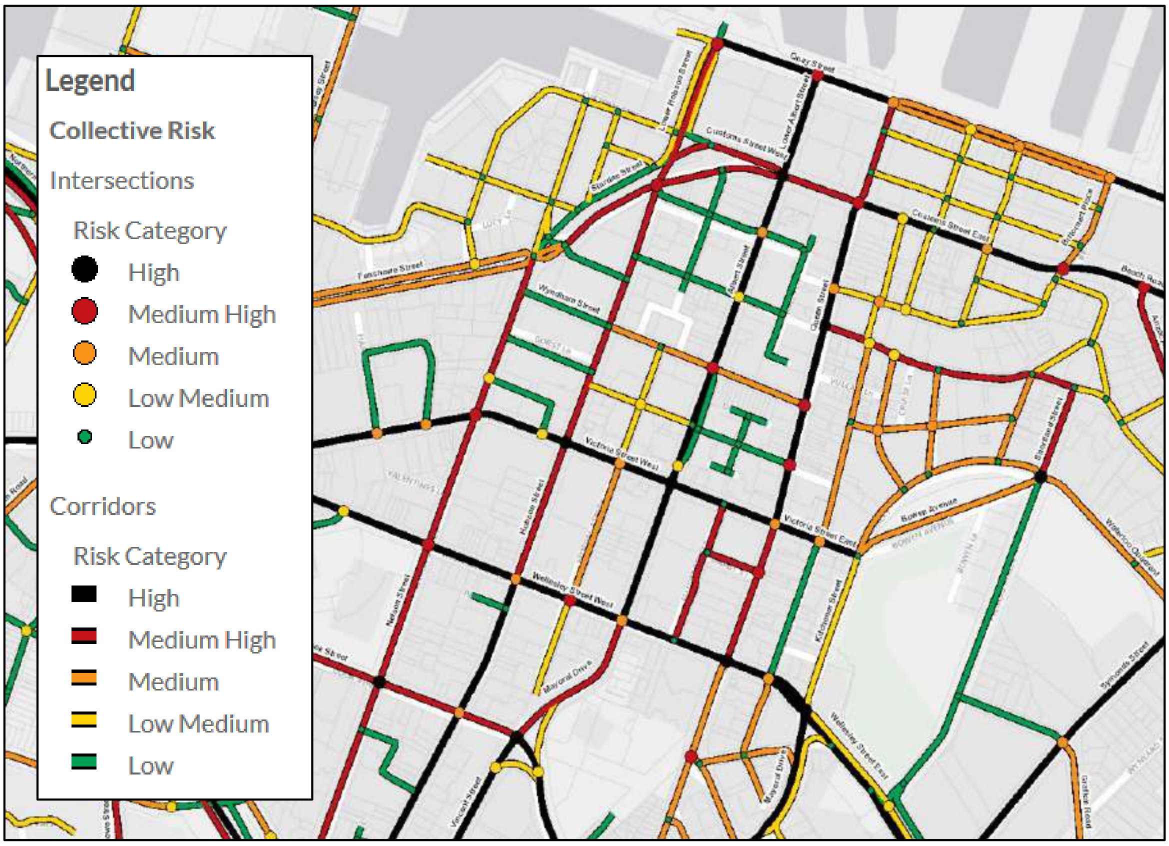


Figure 1. Map showing Urban KiwiRAP Collective Risk metric for central Auckland.

Data

The road centreline used to create the vehicle routing network was taken from Urban KiwiRAP. This data contained Urban KiwiRAP safety metrics, the annual average daily traffic (AADT) count and speed environments. These values were required by the models in the EEM to derive safety metrics.

Further data was added used to refine the vehicle routing network, such as information on the direction of flow along roads which was required to produce a more accurate network. Often this could be determined by viewing online maps and imagery but in some cases the information had to be taken from other data sources.

Network and routing development

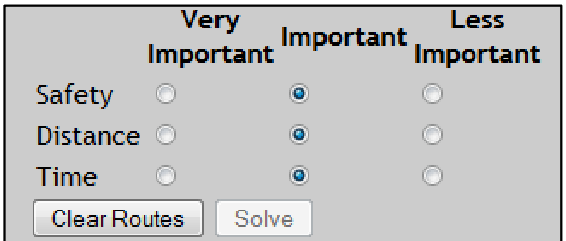
A vehicle routing network contains interconnected links and nodes which represent a collection of roads. Each link contains attributes (such as hierarchies and travel directions) and an impedance value which when each section is traversed, accumulates. The GIS uses Djkstra's algorithm (ESRI, 2014) which aims to solve the network by accumulating the lowest impedance. Depending on the impedance value, different routes between the same points can be created.

Utilising GIS software, a vehicle routing network was created. Each link of the routing network was assigned a value of safety risk, both a Personal Risk value (from Urban KiwiRAP), and EEM predictive risk value. The times taken to traverse each link on the network were calculated using the posted speed limit and the length of the segment.

Using GIS network analysis and routing algorithms, the network was used to identify the safest (lowest safety risk), shortest (shortest distance) or fastest (shortest time) route between two or more locations. Testing of the methodology found that in some instances the safest route was significantly longer than both the shortest and fastest route, and hence would be considered impractical from a road users perspective. Hierarchies and a 'baseline' level of risk were introduced to resolve this problem.

The initial scope of the project involved allowing a user to identify an acceptable level of risk, based on how much further/longer they would be willing to travel compared to the shortest or fastest route. For example, if the fastest route between two locations is calculated as 10 minutes, and the user is willing to travel an extra 10% longer for a safer route, the routing application would then assess the safest route that would take less than 11 minutes. This problem is a variation on the "Resource Constrained Shortest Path Problem" (Irnich & Desaulniers, 2005) which was unable to be solved by the GIS. For this reason, an alternative (and simpler) method was developed using weightings instead.

The weighting system allows users to choose their relative preference for safety, distance and travel time using a matrix (Figure 2). The matrix takes the users input and calculates an impedance value based on what was chosen. If safety, distance and time were all given the same level of importance, these values will be normalised and then combined with each having a weighting of 33.3%. If the user states that safety is very important and distance and time are less important then the weighting returned should be the normalised safety value. However, as noted above, testing found that this weighting would often result in situations where a user would take a convoluted route by only travelling down low hierarchy roads with no respect to either time or distance. To resolve this, the



weighting when safety is very important is capped at 80% safety and 20% distance.

Figure 2. Safety, distance and time user preference matrix

Comparison of safety risk metrics

The EEM and Urban KiwiRAP measures of road safety risk were compared throughout the network and routing development process. During this process it was found that Urban KiwiRAP provided the most reliable predictor of road safety risk for routing purposes. Figure 3 displays some of the

differences between the two risk metrics.

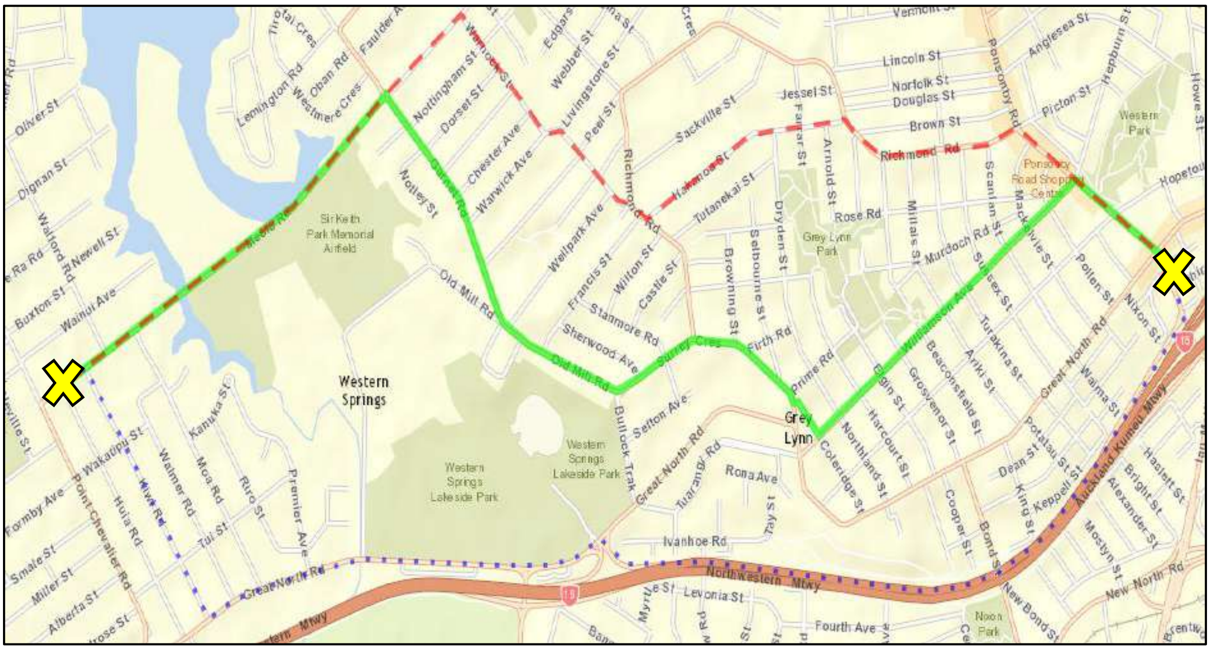
Figure 3. Comparison of EEM (left) and Urban KiwiRAP (right) risk centreline

Through testing it was evident that Urban KiwiRAP was the preferable choice for determining the risk of roads. It was noticed that the EEM risk metric tended to route onto low volume local roads because fewer crashes would be expected to occur in these environments; however, these are often impractical for routing purposes. The EEM models avoided high volume roads (such as motorways) even when there were comparatively fewer crashes, which is not unexpected as the models return average values for safety performance based on the sample of data from which they were created.

The Personal Risk metric from Urban KiwiRAP contrasted the results from the EEM. It analysed many roads with a high AADT as low risk due to them having a relatively low number of crashes for the amount of road use. Some lower volume roads with a low number of crashes were classed as higher risk as the ratio of crashes to vehicle volume was greater.

Web interface

A website was developed to interactively allow users to identify, process and display routes, and to enable users to graphically compare the safest, shortest and fastest routes (Figure 4). Accompanying



the route are some complimentary comparison statistics quantifying the variations between the routes (Figure 5). The statistics provided allows the user to make an educated decision as to which route is the most suitable for them.

Figure 4. Sample output from the routing website displaying the shortest (dashed red), quickest (dotted blue) against the preferred route (solid green).

Figure 5. Sample output displaying the difference between the three routes.

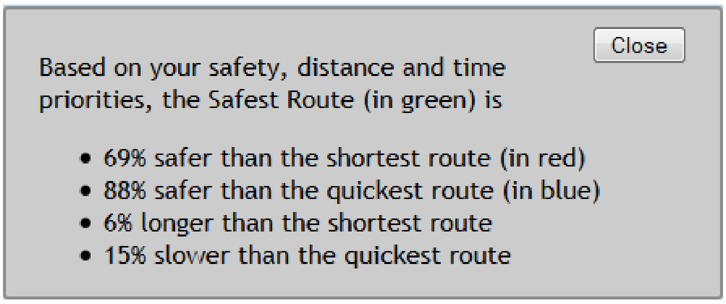
Discussion

The research project demonstrated that integrating safety metrics into a vehicle routing network is feasible.

Suitability of metrics

Road safety risk quantified using the Urban KiwiRAP Personal Risk metric was determined to be a more suitable risk metric than EEM crash prediction models for the purpose of developing a safety routing network methodology. Personal Risk provides a risk value at an individual level and can be accumulated to calculate total Personal Risk along the length of the route.

Safety is often ‘assumed to be inherent in design policies and practices’ (Federal Highway Administration). While this may be true, some roads exhibit better safety performance than others. The International Road Assessment Programme (iRAP) defines three RAP protocols; namely risk



mapping, Star Rating and performance tracking (Brodie, et al., 2015). The Urban KiwiRAP metrics used in this research are derived from the risk mapping protocol and therefore are removed from specific design features of intersections and corridors. Star Rating in New Zealand is presently limited to the high-speed State Highway network. Star Rating is an assessment of the engineering features of a road that contribute to safety outcomes, it does not look at crash history. Roads with exceptional safety features are assigned a 5 Star Rating whereas roads with no or minimal safety features are assigned a 1 Star Rating. Information is currently being collected in urban environments in New Zealand to develop an Urban KiwiRAP Star Rating. When this information becomes available, it is possible that this proactive risk metric may become a better metric for any safety routing calculations than reliance on historic crash performance.

Past research outlined by Navin et al. (1996) explores a number of methods that can be used to calculate and derive road safety. However it appears that these models provide a global safety metric, not something that can be applied to individual roads and therefore be used for routing.

Work by Usman et al. (2010) is promising as they explore how the Negative Binomial model can be applied to road safety. They state that this has 'been found to be the most suitable distribution structure[s] for road accident frequency'. The paper explores how winter road maintenance in Canada can be quantified in terms of safety benefit. Using exploratory data analysis, a range of factors/variables were assessed to determine whether they were statistically significant at the $p<0.05$ level in determining the frequency of accidents. A similar approach would prove beneficial to determining and deriving road safety in New Zealand.

As mentioned, investigation into methods of quantifying road safety that have a greater coverage is needed. This was one of the limitations of this project as 48% of all roads in the study area of Auckland did not have enough historic crash data to successfully derive crash metrics. This may have skewed the results but there was no suitable or comparative safety metrics available.

There needs to be further research into how the EEM and Urban KiwiRAP derive safety. They are both New Zealand specific applications and further development will improve the usability and accuracy of the two methods. Urban KiwiRAP relies on crashes taking place in order to derive and calculate safety metrics (Waibl et al., 2012). Over time, as roads become safer under the Safer Journeys Strategy, it will become increasingly difficult for Urban KiwiRAP to derive safety metrics for all but New Zealand's busiest roads.

Routing development

There are a number of improvements to the underlying routable network that would provide more accurate and reliable outputs. More complete data on the road network as well as investigation into the implementation of the Resource Constrained Shortest Path Problem would benefit further development of this research.

The GIS-based vehicle routing network used in this research was very basic. The centreline used contained only some of the necessary data to develop a robust vehicle routing network. More information such as turn restrictions, access restrictions and travel times are required to develop a more accurate vehicle routing network. Typically, this data is only available through commercial data sets.

This project aimed to be a 'proof-of-concept', thus it is not currently suitable for application. The limitation of this vehicle routing network has been identified and would require further development before becoming usable. It is unknown if data (such as safety) would be able to be added to a commercial dataset. Therefore it would be an option to collaborate and work with a company providing vehicle routing networks. Another approach would be to explore Open Street Map (OSM). OSM uses Volunteered Geographic Information (VGI) to gather and build data.

The method of weighting used constrains the ability for a user to specify quantifiable differences, they are only able to specify variations relatively, not absolutely. To implement the Resource Constrained Shortest Path Problem significant resources would need to be used to develop and implement a tool. This could be done in a number ways, the most useful would be to develop a plugin that would work with ArcGIS, the platform used to develop this project. If a tool was developed that could solve the Resource Constrained Shortest Path Problem this would expand the ability for a user to further control and manipulate the factors that calculate their route.

The methodology applied can easily be altered and scaled to use on different datasets and locations. Any changes to algorithms used simply need to be re-entered and the model re-run if anything changes. The flexibility allows for simple and easy maintenance as well as scalability to incorporate larger areas or more complex networks.

Conclusion

This project has successfully managed to prove that routing using safety metrics is feasible. By testing and comparing the Economic Evaluation Manual and Urban KiwiRAP it was determined that the Personal Risk metric from Urban KiwiRAP was suitable for this application. However there were a number of limitations to this dataset as it does not provide a complete coverage of all the roads in Auckland.

One of the aims for this project was to allow for the user to choose how the route would be calculated in terms of safety, distance and time. As an alternative to the Resource Constrained Shortest Path Problem, a method of weighting and associated matrix was developed that fulfilled this requirement. However it does not provide the full flexibility that would be available by ‘solving’ the Resource Constrained Shortest Path Problem.

Whilst the research has satisfied its original objective, that is, demonstrating that combining safety metrics with a vehicle routing network is feasible, there are a number of areas for improving and refining the safety routing process. Currently there are only a few methods of quantifying and deriving safety for roads. The suitability of using safety data in routing networks has had little study. The study area needs to be expanded to further develop and refine the outcome.

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ASEAN and ADB Implementing New Approaches to Building Road Safety Capacity

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Abstract

Following the Association of Southeast Asian Nations (ASEAN) senior transport officials meeting in May 2011, the Secretariat requested the Asian Development Bank (ADB) to provide assistance to improve road safety in ASEAN. In response, ADB, funded by the Japan Fund for Poverty Reduction, has begun an innovative approach to capacity building that has already been adapted and replicated in other sub-regions. This paper will discuss the model central to the project.

The Road Safety Capacity Building for ASEAN Project commenced in May 2013. Each country has appointed a National Focal Point (NFP) to identify and coordinate information. A team of International Experts were appointed to develop materials and present a comprehensive train the trainer program focused on five key areas. Thirty eight senior Government officers from across ASEAN attended a two week program at ADB headquarters in Manila and will arrange and deliver specific training and associated activities to other colleagues within their country. ADB has appointed a National Consultant to work in partnership with the trainees on a range of activities including development of "pipeline project proposals" for funding consideration investors and donors.

As part of the project, a draft ASEAN Regional Road Safety Strategy document has been prepared and consultation will further refine its directions and contents. The project will reach its conclusion in 2015 and a follow up phase three project is being considered.

Introduction

Road trauma has incredible impact on the health and economic growth of all nations. The United Nations has recognised the importance of dealing with this problem by announcing 2011-2020 as the Decade of Action for Road Safety. In 2011, it was estimated that more than 75,000 people died in road crashes in the ten member countries of the Association of South East Asian Nations (ASEAN: Brunei, Indonesia, Malaysia, the Philippines, Singapore, Thailand, Viet Nam, Laos PDR, Myanmar, and Cambodia) and many more sustained long term injuries. Improving road safety outcomes in ASEAN is not only important for the welfare and economic benefit of the populations of these countries, but given the proportion of the world's population that lives in ASEAN, it will strongly influence whether the aims of the United Nations Decade of Action for Road Safety and the Sustainable Development Goals are reached.

ASEAN is a unique sub-region, with some countries belonging to other organisations such as the Asia Pacific Economic Forum (APEC), and UNESCAP. In terms of the ASEAN structure, road safety is particularly relevant to Transport Ministers, Senior Officers, the Land Transport Working Group and Multi-sector Road Safety Special Working Group (MSRSSWG). The MSRSSWG is charged with the responsibility to mobilise and deliver the Regional Road Safety Strategy through ASEAN.

The ASEAN Secretariat has requested the Asian Development Bank (ADB) to provide assistance to improve road safety in ASEAN in accordance with the directions of the ASEAN senior transport officials meeting in May 2011. ADB consequently prepared a successful submission to the Japan Fund for Poverty Reduction (JFPR), a trust fund funded by the Government of Japan, and managed by ADB. The submission proposed an innovative approach to capacity building that has already been adapted and replicated in other sub-regions. This paper will discuss the model central to the project.

Project history and outcomes

In May 2013, at the ASEAN Multi - Sector Road Safety Working Group (MSRSSWG) meeting held in Vientiane, Laos, the Road Safety Capacity Building for ASEAN Project commenced. Following the meeting each country appointed a National Focal Point (NFP) whose role is to identify and coordinate information on behalf of the country concerned. Soon after a team of International Experts were appointed to develop materials and present a comprehensive train the trainer program focused on five key areas: road safety management, data systems management, police enforcement, safe routes to school and motorcycle safety. Thirty eight senior Government officers from each ASEAN country attended a two week train-the-trainer program at ADB headquarters in Manila. This program was delivered as part of the Asia Road Safety 2014 event hosted by the ADB, Global Road Safety Partnership, International Road Assessment Programme and Global New Car Assessment Programme in June-July 2014.

Having undertaken the train the trainer program the trainees are expected upon return to their country to arrange and deliver specific training and associated activities to other colleagues within their country. In each country, ADB has appointed a National Consultant to work in partnership with the trainees on a range of activities. These include development of “pipeline project proposals” for funding consideration investors and donors. A case study of this approach in Cambodia is provided in Sann, Haworth & King (2015).

As part of the project, a draft ASEAN Road Safety Strategy document was prepared. The development of the draft strategy posed some unique challenges in terms of identifying the optimal approach for a region characterised by diversity in both road safety issues and levels of economic development. The lack of consistent measures of road safety activity and performance led to the need to create new semi-qualitative measures that would not require extensive resources to collect and monitor. Consultation on the draft ASEAN regional road safety strategy is now underway. The section on road safety context and issues in each country will be enhanced by input from national road safety advisors. The revised document will then be considered by ASEAN officials in late 2015 and further development will follow. More details of the draft Regional Road Safety Strategy are provided in Haworth & Klein (2015).

The Road Safety Capacity Building for ASEAN Project has progressed well through various stages and will reach its conclusion in 2015. A follow up phase three project is being considered.

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Exploring the sale of second hand child restraints and booster seats in Victoria

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Abstract

RACV has a strong commitment to providing accurate and useful information to parents and carers regarding child restraint and booster seat safety. The use of second hand child restraints is generally not recommended because the restraint may have been in crash, be damaged, missing parts, or be too old to provide the best protection in a crash. However purchasing a new restraint may not be a realistic option for all families. The current project aimed to examine quality and safety of second hand child restraint and booster seats available in Victoria, and to also investigate their compliance with standards and regulations. A range of online, second hand specialist retailers, resource recovery centres, and markets were explored. Where available, the source, location, brand, model, price, year of manufacture and whether the current standard was met was noted. From these sale platforms, the details of 164 second hand restraints were obtained. Most results were acquired from online sellers (114 restraints) and of these, 16 (14%) were unsuitable for sale. Of the 50 restraints examined in stores, 18 (36%) were unsuitable for sale. Most restraints appeared to meet the current standard however restraints considered unsuitable for sale were found to be worn, damaged, too old or were identified as illegal overseas models. The issue of substandard restraints for sale could potentially be addressed by communicating to parents and vendors about the risks and precautions to take when selling and purchasing second hand child restraints.

Introduction

RACV provides advice on the purchase and use of child restraints and booster seats in Victoria. Only child restraints complying with the 2004, 2010 or 2013 versions of the Australian standard (AS/NZ 1754) can be legally sold and used in Victoria. In addition, only restraints less than 10 years old are recommended for use and restraints that are damaged or have been in a crash should not be used as they may not perform optimally in a crash. Booster cushions do not offer any side impact or head protection and are not recommended for use.

RACV sought to examine the second hand market for child restraints and booster seats to establish the safety and quality of restraints being sold in Victoria. The level of compliance with the standard and regulations was also investigated to ensure the safety of children is not compromised in a crash.

Method

A variety of sources of second hand restraints were explored to identify where potential problems are likely to exist and identify avenues for further action and investigation. The details of 164 second hand restraints were collected from a number of sources including online sales platforms (114 restraints), specialist baby goods second hand retailers (37 restraints), resource recovery centres (7 restraints), second hand and charity shops (0 restraints) and a baby goods second hand market (6 restraints). Second hand charity shops were found to not stock second hand child restraints most probably as a matter of policy.

Results

Overall, the results showed that 21% of restraints were unsuitable for sale. The quality of restraints varied between online and in store. Table 1 summarises the restraints that were examined online.

Table 1. Summary of restraints examined online

	Suitable	Unsuitable	Total
Online store 1	78	14	92
Online store 2	20	2	22
	98	16	114

Of the 114 restraints examined from online stores, 16 (14%) were found to be unsuitable. Of these, 7 were booster cushions, 5 were overseas models, 3 were damaged, and 1 was more than 10 years old.

Table 2 summarises the restraints that were examined in stores.

Table 2. Summary of restraints examined in stores

	Suitable	Unsuitable	Total
Second hand baby goods stores	23	14	37
Resource recovery centres	3	4	7
Baby good second hand market	6	-	6
Charity stores	-	-	-
	32	18	50

Of the 50 restraints examined, 18 (36%) were found to be unsuitable. Of these, 7 were more than 10 years old, 6 had the sticker removed or were worn out, 2 were damaged, 2 were overseas models and 1 was a booster cushion. If stickers displaying information about the year of manufacture and compliance with the Australian standard are removed, parents are not able to accurately determine the suitability of a restraint.

Key Findings

Online stores

There was generally more information about the child restraints available on one online site compared to the other. The listings on both websites tended to be for recent child restraint models, particularly in the capsule and forward facing categories, and therefore these are less likely to be a problem.

While most child restraints examined for sale for this study appeared to meet the standard, booster cushions (not recommended for use) were found for sale and some international restraints (illegal to use) were of concern. Some restraints were damaged and should not have been for sale.

Second hand stores

Many restraints at one store were old and visibly worn and several did not have dates of manufacture, which does not allow parents to make an informed purchase decision. A number had their dates scratched off or removed and one model seemed to have had a new cover put on, which aroused some suspicion about the prior condition of the restraint and the reason for the change.

Resource Recovery Centres

The quality of child restraints found at Resource Recovery Centres was poor and less than half would be suitable for purchase. This is not surprising as these restraints were most likely intended for disposal rather than sale.

Second hand market

All child restraints found at the baby market appeared to be of acceptable quality and met the Australian standard.

Discussion

There is a substantial volume of second hand child restraints for sale in Victoria, some of which were found to be illegal and/or unsafe to use, while many appeared to be suitable and safe to use. It is important for sellers to only sell legal and safe models of child restraints, and for parents to take steps to check they are buying a child restraint that meets the Australian standard and are safe to use.

The research recommended that advice could be offered to parents/buyers to assist in making an appropriate and safe purchase. To address this, RACV has developed a set of tips to help parents purchase a suitable restraint. Information for parents can be found at racv.com.au/childrestraints. This information was communicated through RACV's RoyalAuto magazine, a media release, and social media messaging.

It was identified that some restraints for sale needed to be removed urgently. Given the small number of sellers involved, it was suggested that government could work directly with retailers to ensure unsuitable restraints are not available for sale. On an ongoing basis, this could also involve communication regarding updates on standards and regulations about the types of restraints that can be sold. An expert contact could also be provided to support retailers in making decisions about restraints for sale.

Retailers also have an obligation to be familiar with legal and safety requirements and destroy any restraint that is identified as being unsuitable for sale. Retailers should only sell restraints that meet the Australian standards, are not damaged, in good condition and less than 10 years old. It is also important for buyers to be aware of what to check to ensure they are purchasing a safe restraint, so that the safety of their children is not compromised in the event of a crash. RACV's tips will assist parents and carers make an informed purchase decision and select a suitable and safe restraint for their child.

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What's the ride answer? Australia must take a more integrated approach to motorcycle safety

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Abstract

Australia must take a more integrated approach to motorcycle safety if the desired reduction in serious casualty crashes is to be achieved. Some great progress has been made with motorcycle safety initiatives in different jurisdictions, but a coordinated approach would have even greater outcomes.

Motorcycle use continues to grow in popularity, but in many policy areas there remains a reluctance to embrace motorcycle transport or do things that might be seen as 'encouraging' or supporting motorcycle use.

Within the Safe System approach, the focus on safer infrastructure and safer vehicles is limiting the potential for greater motorcycle and scooter safety outcomes. There are challenges and limitations in terms of making infrastructure more forgiving and vehicles safer, so there needs to be greater focus on 'safer road users' for these vehicle types. Riders are far better off avoiding crashes altogether than relying on the 'system' to minimise injuries in the event of a crash.

Another example is with marketing. In the digital age, state-based road safety campaigns become lost in the blur of social media.

Introduction

The Australian Motorcycle Council (AMC) was formed in 1980 and is the peak road rider representative organisation in Australia. The AMC's membership is made up of the main rider organisations from each state and territory and also includes a number of standalone national associations. The AMC has been active in promoting motorcycle safety in Australia and internationally throughout this time and was a member of the Australian Government's Motorcycle Safety Consultative Committee (MSCC) until funding of this forum was ceased by the Government in 2010.

The call for a national approach to motorcycle safety extends for over a decade. In 2004, the House of Representatives Standing Committee on Transport and Regional Services released its report on an Inquiry into National Road Safety, *Eyes on the Road Ahead*. One of the report's recommendations was the development of a national motorcycle safety strategy. This has never happened.

In 2008 the Australian Government, through the MSCC and with funding support from the Federal Chamber of Automotive Industries (FCAI), hosted the Motorcycle and Scooter Safety Summit in Canberra. The summit produced an extensive list of key recommendations in seven policy areas, but lacked a plan for how these would be progressed. Subsequently, little has happened with many of these recommendations.

Soon after the Canberra summit, the OECD's International Transport Forum held a Workshop on Motorcycling Safety at Lillehammer, Norway. This was attended by representatives from the Australian Government, the AMC and the FCAI. The workshop produced a list of 19 recommendations; however this also lacked a plan for implementing recommendations. The OECD subsequently formed a working group to prepare a report on progressing the workshop recommendations. This was due for publication by the end of 2014, although by mid-2015 this had not occurred.

In 2010, the short-lived National Road Safety Council (NRSC) picked up on the lack of national progress with motorcycle safety and decided to initially focus on one area – rider training. At the NRSC's request, the MSCC to develop a proposal for a national approach to rider training. This was referred to Austroads in late 2010. A number of jurisdictions have commenced separate reviews of motorcycle rider training since that time.

Education

The importance of marketing messages for motorcycle safety was one of the seven areas highlighted at the 2008 summit. This is a subject explored by the Australian Motorcycle Council at the Australasian College of Road Safety conference in Adelaide in 2013.

The significant growth in social media use in recent years has added a significant new dimension to marketing in Australia. There are now over 11 million Facebook users and 2.2 million Twitter accounts.

Video advertisements that were once almost the sole domain of geographically-based television networks are now shared across the country, and around the world. There should be reconsideration of how road safety campaigns are delivered in Australia

This situation of multiple messages in a national market is not new. State-based safety campaigns have been promoted in national motorcycle print magazines for at least a decade. It hasn't been unusual to see an advertisement from New South Wales on one page, and another taking a completely different approach from Victoria a few pages later.

From a marketing perspective, it might be normal to have competing businesses with different approaches, but with motorcycle safety, isn't it trying to 'sell' the same brand?

Road rules

Australia generally has a set of national road rules, with some local interpretations, exceptions and additions. Something of a paradox in relation to a national approach to motorcycle safety exists in the area of lane filtering. It's fair to say that if Australia had waited for a lane filtering to become part of the national road rules, it would have been a long wait.

Instead, New South Wales acted first and after a successful trial, specifically defined and legalised lane filtering from July 2014. Queensland followed with similar rules. Now a trial is currently underway in the Australian Capital Territory and the Victorian Government is running a public consultation process examining the subject.

Whilst welcoming progress in these jurisdictions, we are fast-heading to a state of filtering being defined slightly differently depending on where you live. This is not a good situation for people who travel or who live near a border in a highly-populated area – two such regions exist in Australia.

Rider training

Following a report from the now-defunct MSCC to the now-defunct NRSC in 2010, an Austroads' project has considered development of a national graduated licensing scheme for motorcycle Riders.

One aspect of the MSCC report was a strong recommendation that the motorcycle rider training industry in Australia should be closely consulted as part of any review. The AMC has continued to advocate for a national approach but has been kept completely in the dark on progress of the project over the past four and a half years. Meanwhile, a number of jurisdictions have been undertaking separate reviews of rider training. State rider organisations have been consulted in these reviews.

Infrastructure and motorcycle safety

This is one area where the beginnings of a national approach are underway with some elements. Austroads has two projects underway that are paying particular attention to motorcycle safety. One is entitled Safe System Infrastructure which has looked at motorcycles as a separate road user category. A second is specifically looking at the Austroads Guides to see if additional information specific to motorcycles should be included.

Meanwhile, over the past decade almost all jurisdictions have developed individual projects aimed at improving infrastructure aimed at reducing motorcycle and scooter casualties. These have been a mix of measures aimed at reducing the frequency of crashes and those aimed at reducing severity of injury in the event of a crash.

Conclusion

Motorcycle safety continues to be one of the most frequently discussed aspects of road safety in Australia, but despite significant amounts of knowledge and goodwill, progress has been very slow in many areas.

Other countries have done far better – *The Government's Motorcycling Strategy* from the United Kingdom is one example. The *National Strategy for Motorcycle and Mopeds* from Norway is a joint production of the Norwegian Government and the Norwegian Motorcycle Union – the country's equivalent of the Australian Motorcycle Council.

Australia has taken a proactive to cycling, with the Austroads-funded Australian Bicycle Council responsible for implementing a national cycling strategy – which includes many safety elements.

This year, the Senate Standing Committee on Rural and Regional Affairs has held an Inquiry into Aspects of Road Safety in Australia. The AMC expects that this Inquiry – just like the House of Representatives inquiry before it in 2004 – after consideration of all the evidence presented, will make a recommendation for a national approach to motorcycle safety.

Will this be a case of history repeats, or is there now the will and desire to take a united approach?

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Examining novice education: What can we learn from a compulsory program delivered to both mature-age and young pre-learner licence drivers?

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Abstract

This paper reports results from a qualitative evaluation of a compulsory pre-Learner driver education program within the Australian Capital Territory(ACT), Australia. Two methods were used to obtain feedback from those involved in the delivery of the program as well as those who participated in programs. The first, semi-structured interviews, was undertaken with class room teachers who run the program in their schools, group facilitators running the program with more mature-age students at private facilities (*n* = 15 in total), and former participants in both school-based and private-based versions of the program (*n* = 19). The second method used an on-line survey for students (*n* = 79). Results from both methods were consistent with each other, indicating that strengths of the program were perceived as being its interactive components and the high level of engagement of the target audience. There was strong support from young and mature-age students for the program to remain compulsory. However, consistent with other findings on novice driver education, mature-age participants identified that the program was less relevant to them. It may be that to have greater relevance to mature-age learners, content could address and challenge perceptions about behaviours other than intentional high-risk behaviours (e.g. low level speeding, fatigue) as well as encourage planning/strategies to avoid them. While a longer term, outcome focussed, evaluation of the pre-learner education program is needed, this study suggests that the program is well received by pre-licence drivers and that teachers and facilitators perceive it as both effective and beneficial.

Introduction

Young drivers, throughout the world, have persistently experienced higher crash rates than older drivers (Bates, Davey, Watson, King, & Armstrong, 2014) with a number of factors contributing to this risk (Shope, 2006). Driver education and training are countermeasures that are often used in an attempt to address the higher crash rates experienced by young drivers (Bates, Watson, & King, 2006). While ‘driver training’ and ‘driver education’ are frequently used interchangeably, the terms differ in their meaning (Beanland, Goode, Salmon, & Lenne, 2013).

Driver training operates by introducing basic vehicle and driving skills before developing and enhancing these skills and rests on the assumption that highly skilled drivers are safer drivers (Isler, Starkey, & Sheppard, 2011). However, thus far, research evidence has failed to support that traditional driver training prior to or as part of the licensing process reduces post-licence crashes or reduces traffic violations (Elvik, 2010). In some cases, driver training programs may increase crash risk for young drivers by encouraging individuals to obtain a licence at a younger age (Senserrick, 2007).

Driver education is broader than driver training and often may not include a practical driving component. It tends to focus on drivers obtaining driving knowledge and providing information about road safety, with a key focus being on the motivational foundations of driver behaviour (Christie, 2001). Recent driver education programs have had a strong focus on higher-order skills training including cognitive training, hazard perception training and insight training. Although the research evidence is limited, it appears that this type of training program may improve the skills that are being targeted; however the effect on crashes is unknown (Beanland et al., 2013).

The focus of this paper is on pre-learner driver education. The Australian Capital Territory (ACT) government instigated the *Road Ready* program in 2000. The course is a compulsory pre-licence driver education course delivered to all individuals who are intending to obtain a learner licence. It is offered to adolescents at year 10 level (around age 15-16 years) through high schools within the region as well as through other venues for more mature-age novice drivers and young people unable to receive the program through a school. It does not contain any practical training components. Further information regarding the *Road Ready* program is available from (Lennon, Bates, Rowden, Haworth, Williamson, Kiata-Holland & Murray, 2014).

In total, around 10,000 pre-licence drivers complete the program annually, with the majority doing so through a state-based or private high school (approximately 54%) or a *Road Ready* Centre (approximately 37%). This paper reports on an evaluation of this program undertaken as part of a commissioned review. By doing so, it adds to the extant knowledge as it considers both young and more mature novice drivers (as opposed to just young drivers).

Method

Participants

From a list of 32 state and private high schools in the ACT, 23 schools representing different locations and demographic profiles were approached to participate. Of these, six agreed (4 state; 2 private) to allow the researchers to approach their staff and students. The private provider of the program, Freebott, who operate the *Road Ready* Centres, also consented to staff participation.

Interviews: A total of 15 facilitators and high school teachers (8 men, 7 women) and 19 students (13 young; 6 mature-age; in total, 6 boys, 7 girls, 3 men, 3 women) agreed to be interviewed. Facilitator and teacher experience in delivering the program varied from those who were in their first year of doing so to those who had been part of the original cohort of teachers in the initial year of the program (that is, in year 2000). Students were interviewed within 1-8 weeks of completing the *Road Ready* program

On-line survey: A total of 79 students completed the survey, of which the majority were aged 15-20 years (n = 54). Most of the students had obtained their Learner licence (n = 60) since completing the *Road Ready* course. Ethical clearance was provided by the Human Research Ethics Committee, Queensland University of Technology.

Procedure

Interviews. Qualitative, semi-structured, in-depth face-to-face interviews with teachers (high schools) and facilitators (Freebott) were held in their workplaces. Two facilitators were interviewed by telephone due to limitations of time and availability. Interviews ranged in duration from 30 to 60 minutes, with most being around 35 minutes. Detailed notes were made during each interview and some interviews were also audio recorded. Written consent for the recordings and notes was obtained prior to interviews. Teachers and facilitators were offered cash compensation (AU$25) for their time and effort.

Questions for facilitators and teachers focussed on perceptions of the strengths and weaknesses of the program content as well as its effectiveness at engaging the target group, aspects that might need revision, and suggestions for improvements to the program. For students, questions focussed on their perceptions of the relevancy of the program content, most and least enjoyable aspects, and the pacing of the program.

High school students were interviewed in person at their schools, while *Road Ready* Centre students were interviewed by telephone. High school students provided written consent from a parent/guardian prior to the interview, as well as consenting in writing themselves. For non-school based students, a verbal consent protocol was used. Interviews with students were 10 minutes long and not recorded, but detailed notes were taken. Students were offered $AU10 in cash or gift voucher as acknowledgement.

On-line survey: After pilot testing, an anonymous survey was developed and posted on-line. Previous students (from schools or *Road Ready* Centres), were invited to respond. Initially the survey was available for 3 weeks during May 2014. In order to recruit additional mature-age students, the survey was made available through *Road Ready* Centres again in September 2014. Student participants in the survey were eligible to enter a random draw for one of four gift vouchers to the value of $50 as acknowledgement.

Questions for the survey asked about the relevancy of content, most and least enjoyable aspects (consistent with the interviews) and also asked what messages students recalled from the program. However, there were age-relevant differences between the survey versions for younger versus mature-age students. One additional question was added to the student survey for the second data collection period only (see bottom of Table 1) in order to further gauge perceptions of the relevance of the program to those students who had obtained a licence since completing the program: "Now that I am driving, I can see how important the *Road Ready* program is" (all ages, only if also holding L or P licence). The full list of survey items is displayed in Table 1.

Results

Interviews

Format of program delivery.

Although the research team only visited 6 schools (government and private), it was clear that the program is offered in a variety of formats with varying costs levied to students completing them. Programs were offered within the curriculum in the following formats: 1 hour-per-session weekly; 1 hour weekly as after school, optional program; intensive 3 hour sessions over 4 weeks; and intensive 2-3 day programs within the school calendar (but not part of the curriculum). Some schools charged a fee for attendance ($20-50) while others provided the program free of charge. For some schools the fee was used to allow purchase of equipment that then supported the experiential activities of the program (e.g. speed radar guns; 'beer' goggles) and for some, fees were used to cover the after-school staffing costs. All teachers believed that the fees represented a cost saving to students since the *Road Ready* Centre courses were known to charge more, though there was variation in teachers' beliefs about the exact cost of the external programs (fees of $140-200 were cited; actual fee at the time was $160). *Road Ready* Centres offer the program in a number of formats too. These include: 2 day intensive weekend; mid-week 3 evenings; and 2 day intensive daytime during the week.

Teachers in schools appeared to perceive the *Road Ready* Centre-delivered program as easier for students to complete. There were perceptions that private providers did not require students to complete the program workbook, and that this somehow detracted from the quality of the program. Some teachers also thought that a weekend intensive program format did not have the same impact as one delivered over a more protracted period of time. Comments from some students on the structure of the program suggested that it was not always offered in the form most convenient for them (e.g. weekly session after school for 12 weeks; weekend session with strangers rather than school mates).

Overall relevance and effectiveness.

The *Road Ready* program was very positively regarded by all the teachers and facilitators who were interviewed. Content was perceived as pitched at the right level for the age group (adolescents) and effective for young people in raising awareness about the risks and responsibilities of driving. Program duration was seen as appropriate. Some interviewees acknowledged that a few students appeared to be motivated solely by the mandatory aspect of the program.

Interviews with young students (15-20 year olds) suggested that they mostly enjoyed the program and thought the content was relevant to them personally and their age group. Only one young student thought the program should not be compulsory. However, there were quite a few students who said that they thought the program was too long or had repetitive elements in it, or content that had already been covered in the normal school curriculum, and could therefore be shortened. Most young students thought that pacing of the content was appropriate pacing for them, though the students who had commented that the program might be too long also thought that it was a bit slow in places. Some students commented that they had hoped that the sessions would prepare them better for the test or for the practical aspects of driving. While some reported that when they reflected back, they were pleased that it had not included these aspects, others maintained that the program ought to have them.

Perceptions of the strengths of the Road Ready program.

Teachers and facilitators perceived the highly interactive and discussion-based design of the activities in the program as a strength, engaging students well and encouraging them to talk to one another as well as to share their views with the larger group. Interactivity was seen as facilitating peer learning as well as more likely to draw on the combined experiences of the different people in the groups. These qualities were also regarded as catering to differences in student learning styles as well as more effective in bringing about student attitudinal change. However, *Road Ready* facilitators noted that it was harder to ensure this with groups that had wide cultural diversity or included mature-age students.

Generally activities with the greatest use of interaction were those that the majority of facilitators and teachers regarded as working the best and having greatest student engagement, so it tended to be these rather than whole modules that were identified as working best. Activities designed to convey the complexity of the driving task and its demands on coordination, attention and cognition were identified as highly interactive, engaging and fun, as were those about the impact of drug or alcohol impairment. Some interviewees thought similarly about the activities on speeding behaviour, but views were more mixed, with some finding speeding a challenging content area to deliver and noting that students struggled to understand some of the key messages and concepts. This may have been partly due to the students' lack of driving experience to draw on and relate the material to. It may also have resulted partly from the nature of some of the activities, such as calculating stopping distances, which students with poorer maths ability may have found challenging.

Activities on the impact of crashes, which utilised the video footage, were cited as effective by almost all the facilitators and teachers, and as putting "a human face to the outcomes of poor driving decisions". Use of the real life story of local teenagers was perceived as stimulating student reflection on, and subsequent discussion about, the consequences of risk taking behaviour. The inclusion of longer term negative outcomes, such as permanent disability, was also seen as useful in showing students that death is not the only potential consequence from a serious crash. Several teachers and facilitators reported that students had commented that the 'Mel's story' video was a "reality shock" for them. However, the sobering effect on students of this content meant that teachers/facilitators did not regard it as enjoyable for students, though it was seen as engaging them.

Student comments were consistent with those of teachers and facilitators. Interactive components or activities were reported as the most enjoyable and engaging parts of the program by both young and mature-age students, with "Driving is a complex activity" (Module 3), the use of the beer goggles (Module 8), and speed radar gun (Module 7) specifically identified in this respect by most students. Some also thought that the interactive content could be expanded in the program. Similarly to the teachers/facilitators, young students identified the videos and material related to Mel's story, which is essentially a short documentary account of the circumstances and outcomes of a real crash involving a group of local teens including Mel, a passenger who sustained permanent brain damage, as the least enjoyable or most challenging aspects of the program. They found these "distressing" and "scary", though some also commented that the thought provoking aspect of this material was effective. Young students indicated that they liked learning in groups, liked having variety in the sessions and activities and appreciated the teacher/facilitator skill and attention to establishing a learning environment.

Teachers and facilitators identified program content and relevance as important strengths. Comments included that the program "gets students to think about what it means to be a road user" especially a driver, and raised their awareness of risk, and got them to appreciate the responsibility and consequences of driving. One teacher mentioned that he thought that activities designed to encourage students to think about the planning aspects of driving and the role of anticipating other drivers' behaviour, as well as considering the role of patience and tolerance were important. However, there were mixed views among teachers in relation to the alcohol and drug topics in the program, with some regarding this as timely for the age group as they were likely to already be exposed to drugs and alcohol, while others regarded it as premature, and that 15-16 year olds were unlikely to have had sufficient personal experience with such things to make sense of the issues or feel them relevant to themselves. Young students' views reflected a similar dichotomy, but for different reasons: some students regarded this content as already covered in other parts of their school curriculum and therefore less relevant, while others, as already mentioned, found the activities associated with this content amongst the most enjoyable and engaging.

Mature-age student comments identified that, although most had enjoyed the program and thought it should remain compulsory, the content was seen as less relevant to their age group, and less targeted towards them, with the focus on intentional risk-taking and the potential consequences of this. Some mature-age students commented that there should be more content on the road rules for their age group. One person commented that having to take a full two days off work in order to attend the program represented a challenge and a cost. One person noted that the fear-based aspect of part of the program was unenjoyable and not needed, and others noted that the use of the video-based material was emotionally challenging for them. Several people suggested that programs should be offered that catered specifically to mature-age people and that these could be shorter in recognition of their maturity. Mature-age students cited their perceptions that the program raised awareness of specific safety issues (especially speeding) as well as general driving safety risk and the seriousness of crashes as reasons that it should remain compulsory.

***Aspects of modules or program which are less effective, challenging to deliver or which students like/enjoy least*.**

The materials and some activities within the program differ in the school-based and *Road Ready* Centre-based programs. This appeared to affect perceptions of the effectiveness of some modules and the ease (or otherwise) of delivering them. Topics where the concepts are complex, such as the factors that increase the risk of particular types of novice driver crashes (Module 3; 'Where, when and how crashes occur'), were experienced by the majority of teachers and facilitators as challenging to deliver. In particular, the concept of exposure and relative risk are difficult to convey in simple and face-valid ways to young students. Moreover, for this particular module, attempts to keep program materials current appeared to have exacerbated the difficulty by supplying graphics that require a greater level of teacher/facilitator-driven input to translate for students. In addition, there appears to have been drift in the degree of compatibility between the exercises that relate to understanding the crash statistics in the student workbook (used extensively in schools) and the updated materials. Stimulus questions in the workbook for this module do not always relate to the updated visual/graphic materials. Those topics where the risk or safety aspects are less obvious or common amongst other drivers (such as low level speeding) were also highlighted as more challenging to deliver.

Four modules drew comments from teachers and facilitators that they were less relevant or useful. Module 12 (‘Can I practise please?’) which focuses on encouraging students to plan how they will get driving practise (and how they might negotiate this with licenced drivers (e.g. parents in the main), was regarded by some facilitators/teacher as very important while others regarded it as likely to have little impact and therefore of limited value. Similarly, Module 10 (‘Choices it’s up to you’), designed to encourage students to reconsider the thought processes involved in risky driving decisions was highly regarded by some while others found it both challenging to deliver effectively and of little relevance to students. Module 11, on losing your licence and Module 2, which considers the costs of driving and crashes were widely perceived as less relevant/useful. Teachers in particular thought that school-aged students found the concept of losing a licence difficult to relate to since they are not yet dependent on having a licence. Similarly, material on the expenses associated with driving was seen as too removed from the experiences of most students of this age. Student comments were consistent with those of teachers, identifying the statistics of crashes, costs of crashes or the costs of running a car as unenjoyable, with some perceiving these as “theory” and less relevant as well as less interesting.

Some facilitators thought that the alcohol and drugs module and workbook materials needed revision to give more emphasis to impairment and if possible to include more effective drug education. The message was regarded as not being clear enough in the program and some facilitators commented that they would prefer that the materials take a clear stance and advocate ‘drink **or** drive’ more clearly. Facilitators also noted that the program targeted young people well but that this meant there was a lack of relevance of the content for mature-age people and people from non-English speaking or culturally and linguistically diverse backgrounds (NESB, CALD).

On-line surveys

In total, 79 students responded to the on-line survey, with the majority (n = 54; 68%) being young (15-20 years). Of the 25 mature-age students over half were aged over 30 years (14, 56%) and 11 (44%) were 25-30 years. Six (24%) of the mature-age group had previously held a drivers’ licence in another country (e.g. Canada, NZ, India, China). Most students (76%) had obtained their learner drivers’ licence since completing the program.

Questions were designed to focus on the same general areas as those in the interviews, particularly student perceptions of the content as well as the process of the program, the extent to which they regarded the program as relevant to them, and whether they believed it should be compulsory for licensing. Responses are summarised in Table 1. ‘Strongly agree and ‘Agree’ and ‘Strongly disagree’ and ‘Disagree’ have been aggregated into ‘Agree’ and ‘Disagree’ respectively.

Consistent with the comments from interviews, almost two thirds of students agreed that the program was very relevant to them (65%), while over three quarters disagreed that it was not relevant to driving (85%). However, there were differences between mature-age and younger students, with mature-age students significantly more likely to disagree that the program was relevant to them, (32% of mature-age versus 7.5% younger; χ^2 (1) = 7.803, p < .005) as might be anticipated from comments of mature-age students in the interviews. This difference was not a product of previous driving in another country, since all the previously licensed students either agreed or strongly agreed that the program was relevant to them.

It appears that the messages in relation to the complexity of driving (item 1) and the importance of challenging one's attitudes to risk-taking (item 4) were understood and recalled by students, with high levels of agreement on items related to these aspects of the program (81%, 65% respectively). In addition, almost all the free text responses to a later item ("What single point students had . Responses in relation to the interactive aspects of the program, (items 2, 10, 13) were consistent with comments from the interviews, with two thirds agreeing that they had liked interacting with others (68%) and most disagreeing that there was not enough interaction (82%) or that there had been too much discussion (81%).

Responses to items about whether students found the modules interesting (item 3) suggested that experiences varied. It seems likely that most participants (66%) found at least some modules interesting. At the same time, around a third of participants (34%) are likely to have thought some modules were boring (item 16). As the survey did not ask about specific modules, the level of detail here is very general. However, open-ended questions on which module had been the most enjoyable identified Modules 8 and 9 (Drugs and alcohol content, respectively) followed by Module 4 (Driving is a complex activity) and Module 7 (speed) as the most nominated, consistent with findings from the interviews. It also appears from the qualitative comments that it was the level of interactivity involved, or their engagement with the activities used in these modules (e.g. 'beer goggles', games, simulations) that was important to students enjoying them. Those that were experienced as fun to do were more interesting. For instance: "*Module 4 because the activities were interactive. It was fun to laugh as yourself and others failed the activity, but it really showed how hard it is and made you think more about what goes into driving a car*"
and "*our course facilitator (name) was great and made the course interesting, interactive and enjoyable.*" A third student put it: *"Module 9, because we used the beer goggles and that was a fun and interactive activity."*

Some students commented that where they had been surprised by the facts or figures associated with an aspect of driving (e.g. the impact of greater speed on stopping; complexity of driving task; impairment from drugs or alcohol) this had increased their interest and enjoyment of the module. For instance, one student commented: "*the activity we did in class* [driving is a complex activity] *really showed how much of your attention needs to be on driving and looking out for hazards/signs. I was amazed that my partner is able to have a conversation, listen to the radio AND drive at the same time*." A second student indicated that Module 7 on speed was the most enjoyable because: "*I found this module the most interesting and therefore the one that I enjoyed the most. I found the facts and statistics about a driver's speed on the road really impacting. It really made me aware about my speed when I'm driving and also when I'm in the car with someone else, I now understand more about speed, what can occur*". One student mentioned that Module 5 on hazards was the one that he/she was most likely to refer to having learned from since completing the program.

In relation to the least enjoyable module, Module 2, the impact of road trauma (containing "Mel's story" video) was most nominated, primarily because of its graphic and confronting nature, which is also consistent with comments from the interviews with students. The anti-speed campaign material contained in Module 7 was also mentioned by one student as having a similar effect: *I didn't exactly not enjoy any of them, but module 7: Speed, --those videos from* [the state of] *Vic*[toria] *were quite frightening and full on and I didn't think they would want to show me, a 15 year old, that content. Having said that, it did make me fully aware of the possibilities of crashing. So I am not saying, don't show them, but maybe pick two or three to show*. There were also 6 students (of the 89) who nominated the graphic material as something they would change about the program (remove it or cut it down). Such responses are in keeping with research on fear-based road safety advertising, which has suggested that as well as being confronting and unpleasant, graphic images of road injury is ineffective (Lewis, Watson & Tay, 2007; Lewis, Watson & White, 2008). This appears to be particularly the case with young men, and thus has implications for programs that attempt to influence this group.

Duration of the program appeared to be perceived as appropriate, with 82% of students disagreeing that the program was too short (item 11) or too long (71%, item 15). Most also appeared to have found the sessions helpful in their learning (82% disagreed that sessions were not helpful).

Table 1: Student responses to the survey (process and content of Road Ready program)
(most frequent response in bold)

Question wording	***n***	**Disagree**	**Somewhat agree**	**Agree**
1. RR was very effective in helping me understand how complex driving is	79	8.3% (7)	10.1% (8)	**81.0% (64)**
2. I liked being able to interact with other students during RR sessions	79	16.4% (13)	15.2% (12)	**68.4% (54)**
3. I found some of the modules in the program very interesting	78	10.3% (8)	23.1% (18)	**66.7% (52)**
4. Doing RR challenged my attitude to risk taking on the road	78	20.7% (16)	20.5% (16)	**65.4% (51)**
5. RR is very relevant to me	78	15.4% (12)	15.4% (12)	**65.3% (54)**
6. The program didn't meet my expectations	79	**87.3% (69)**	5.1% (4)	7.6% (6)
7. Overall, I didn't like the program	79	**87.4% (69)**	6.3% (5)	6.3% (5)
8. RR didn't seem relevant to driving	79	**84.8% (67)**	7.6% (6)	7.6% (6)
9. There was too much filling in of workbooks	79	**83.5% (66)**	8.9% (7)	7.4% (6)
10. There wasn't enough interaction in the activities	79	**82.3% (64)**	10.1% (8)	7.6% (6)
11. RR is too short	79	**82.3% (65)**	15.2% (12)	2.5% (2)
12. The RR sessions didn't help me learn	79	**82.3% (64)**	7.6% (6)	10.1% (8)
13. There was too much discussion in the activities	79	**81.0% (64)**	8.9% (7)	10.2% (8)
14. There was too much content in RR for me to absorb or remember	79	**74.7% (59)**	17.7% (14)	7.6% (6)
15. RR takes too long	79	**70.9% (56)**	15.2% (12)	14.0% (11)
16. Some modules in the program were boring	78	**64.4% (52)**	19.2% (15)	15.4% (13)
17. The RR materials were too old/outdated	79	**48.1% (38)**	32.9% (26)	19.0% (15)
18. Videos in RR are too old	79	22.8% (4)	32.9% (26)	**41.3% (35)**
Questions specific to age group				
(young) Schools should continue to deliver the RR program	54	3.8% (2)	9.3% (5)	**87.0% (47)**
(young) RR should involve parents as well as students	54	**50% (27)**	27.8% (15)	22.2% (12)
(young) RR should not be compulsory	54	**68.5% (38)**	14.8% (8)	16.7% (9)
(young) Now that I am driving I can see how important the program is	49	8.2% (4)	8.2% (4)	**83.7% (41)**
(mature-age) RR should remain compulsory for everyone	25	12.0 (3)	4% (1)	**84.0% (21)**
(mature-age) RR should not be compulsory for people over 25 years	25	**76.0% (19)**	0	24.0% (6)

However, while three quarters of students overall (74%) disagreed that there was too much content to absorb, it should be noted that there were much higher levels of agreement (including 'Somewhat agree') on this question among younger aged students (31%) than mature-age (12%). While this was a non-significant difference statistically, it approached significance (χ^2 (1) = 3.430, p =.054, Fisher's exact test), suggesting that the quantity of material in the program may present difficulties for some younger students. Students of both age groups appeared to think the program should remain compulsory for everyone. There were also very high levels of agreement (83%) that students appreciated the importance of the program once they began driving (additional question for September sample), though the sample size (n = 49) for this question was smaller due to not all students having obtained their Learner Licence at the time of the survey.

One of the final questions asked for free-text suggestions as to which aspects of the program students would change. A variety of suggestions were made, including that the program should be more practical (2 students), or have more attention on the content of the road rules (6 students) or that no changes were needed (11 students). Comments from 9 students highlighted that the videos ("Mel's story", anti-speeding road safety messages, driving hazard detection footage) were in need of updating so that they looked less dated and would be less distracting. As mentioned above, 6 students also thought the videos of road trauma (drawn from previous road safety television campaign material) were too graphic. Overall almost all students appeared to have liked the program (69/79) and there were a lot of free-text, positive comments about the program or its value to them at the end of students' survey responses.

Discussion

As the *Road Ready* program is compulsory for both young and mature-age pre-learner drivers, the evaluation provides an important opportunity to examine the differences in qualitative experiences between the two types of pre-learner. In relation to the processes of the *Road Ready* program, it is evident that the program has been delivered in quite different ways in the various schools and the *Road Ready* Centres, and within the schools, with differing levels of resourcing. While the feedback from both those who delivered the program and learners was positive overall, it is likely that the quality of the learning experience and the degree to which students are challenged to address attitudinal and motivational aspects of novice driving also varies. Engagement is critical to this learning process (Carini, Kuh, & Klein, 2006). Almost all those who provided feedback agreed that the interactive aspects of the program were the most enjoyable to deliver and to participate in, as well as the ones most likely to encourage engagement. Thus it would seem that the program might benefit from increasing the number of interactive activities and ensuring that all modules/topics include this type of approach. Facilitators, teachers and participants were of the view that the program currently has a lot of interactive activities, yet also noted that there was room for more. Student feedback on their experiences in relation to activities was consistent with that of facilitators and teachers: identification of the modules that were most enjoyable or interesting appeared to be on the basis that they were the most interactive and engaging.

One potential implication arising from student views about interactive materials as the most engaging and interesting, is that these may be more effective at addressing underlying attitudes and challenging learners to reconsider their views and behaviour. Other authors have reported that at tertiary education level, interaction among learners, either in the form of activities or group discussions, increases learning of concepts (Smith et al, 2009) and academic performance (Freeman et al, 2014). The authors acknowledge that influencing attitudes and beliefs can be more difficult to achieve than aiming to increase knowledge acquisition. However, it is probably easier to do this prior to or early in the licensing process given the relative youth and level of inexperience of typical novice drivers. Among students, the high levels of agreement with the items from the on-line survey in relation to challenging risk-taking behaviours and the complexity of the driving task would suggest that the program in its current form is already perceived by recipients as effective in these respects.

Any revisions to this program should also take into account student feedback on the current use of fear-based content. As highlighted above, students found the graphic content of some of the materials (e.g. from road safety advertising videos) very uncomfortable and nominated this aspect of the program as the least enjoyable. Research in the area of road safety messaging has found that fear-based approaches are ineffective, particularly with the primary target of countermeasures to risky driving behaviours: young men. Despite the comments from both students and facilitators and teachers that these aspects of the program are valuable and effective (even though confronting), the evidence would suggest that they should be replaced (Lewis et al., 2007; Lewis et al, 2008). Replacement materials could focus on interactive content that avoids the use of appealing to strong negative emotional responses.

As might be expected, given that the program was designed for young people, mature-age learners appeared to find the program useful but somewhat less so than younger participants. Despite this view, mature-age students thought the program should remain compulsory for everyone, including their age group. Research on novice driver crash risk suggests that those factors related to attitudes that support risky driving behaviour, or to the propensity to make riskier decisions (e.g. impulsiveness; susceptibility to peer pressure) improve with age and maturation of the executive decision-making functions of the brain (Gogtay et al., 2004; Mayhew, Simpson, & Pak, 2003). Thus, mature-age learner drivers are less likely to need, or to benefit from, education related to these aspects of driving. As attitudinal factors and propensity for risk-taking are the primary targets of effective learner/novice driver education programs, and are major components of the *Road Ready* program, the content of the program for mature-age pre-licence drivers may not be as relevant as it is for young pre-licence drivers. This was acknowledged by some of the mature pre-learners interviewed within this study. The level of endorsement of ‘disagree’ among mature-age students in response to the survey item on content relevance also supports this interpretation. The *Road Ready* program could likely be modified and shortened considerably for mature-age pre-licence learners, or alternatively, it could be voluntary for pre-licence drivers who are 25 years or older.

Some teachers within this study reported that they believed the drug and alcohol content within the *Road Ready* Program was not relevant for the younger pre-learners. However, the average age at which individuals within Australia report having their first full alcoholic drink is 14 years (Australian Institute of Health and Welfare, 2011). This suggests that content on drug and alcohol is relevant for this age group and should therefore can be included in driving education programs, particularly given recent research with drivers aged 17 to 25 years that has found that over 20% of the sample had driven under the influence of alcohol in the past month (Harbeck & Glendon, 2013).

Strengths and limitations

This research has some important strengths. Firstly, this study used both qualitative and quantitative methods, allowing for a limited level of statistical analyses of the responses to support the qualitative findings.. Additionally, the sample included students and teachers from both publically funded and fee paying schools throughout the ACT. However, while we have noted aspects of the way in which the program is delivered, financial and time constraints precluded an attempt to formally assess the impact of these differences. This is a limitation of the study and one that would be important to address in future, particularly to determine whether the program is essentially the same across the different providers and contexts in which it is delivered. This is a clear and important limitation to our study. In addition, this research did not consider the longer-term impact of the education program on crashes and offences or long term road safety beliefs, and there is an obvious need for a quantitative outcome evaluation to provide such information. Another strength of the study is having feedback from both younger and mature-age students. However, a limitation of this for both age groups is the self-selected nature of participation. It may be that our sample was unduly positively disposed towards the program. There was evidence that some students neither enjoyed the program, nor thought it useful, with one person stating the view that it was a "revenue raising scheme". As there were only a few such comments, we have no way of knowing whether this was because few people thought this way or because of our sample was biased. Finally, there is great diversity in the range of driver education and training programs. Thus, there is a need for both more process and qualitative evaluations to enable a greater understanding of what is a very heterogeneous field.

Conclusions

The findings from this study indicate that the *Road Ready* compulsory education program targeting pre-learner drivers is well received by students, regardless of age, and those who instruct them. However, comments from mature-age students suggest that they do not feel as well catered for by the current *Road Ready* program as young people do. It may be that mature-age learner drivers are less likely to need, or to benefit from, education related to reducing high-risk driving behaviours. If programs are to include both young and mature-age novice or learner drivers, content for mature-age people should ideally target aspects of safety that are the most relevant for them. This could potentially include material designed to inform mature-age drivers about the crash risk of low level speeding, low-level impairment (e.g. blood alcohol concentrations below the legal limit), fatigue and distraction and to challenge misconceptions about these behaviours as well as encourage planning/strategies to avoid them.

Our findings suggest that programs should be designed to maximise student-to-student interaction, and be learner-centred. In the current study, this seemed to be just as important for mature-age learners as for young learners. Feedback from teachers, facilitators and students all indicated that the interactive nature of the program was very important to student engagement and interest level. We suggest that an implication is that such design features are more likely to ensure effectively influencing the underlying attitudes and beliefs about risky behaviours and risk-taking (including low-level risky behaviours more relevant to mature-age drivers).

The positive outcomes of this process evaluation suggest there may be value in jurisdictions implementing education programs targeting pre-learner licence drivers. However, for the *Road Ready* program in particular, an outcome evaluation would be useful in better determining whether the program has had an effect on safety of novice drivers (e.g. offences and crashes) and on their attitudes and beliefs in relation to risky driving behaviour.

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Sharing social space with strangers: setting, signalling and policing informal rules of driving etiquette

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Abstract

Recent research suggests that aggressive driving may be influenced by driver perceptions of their interactions with other drivers in terms of 'right' or 'wrong' behaviour. Drivers appear to take a moral standpoint on 'right' or 'wrong' driving behaviour. However, 'right' or 'wrong' in the context of road use is not defined solely by legislation, but includes informal rules that are sometimes termed 'driving etiquette'. Driving etiquette has implications for road safety and public safety since breaches of both formal and informal rules may result in moral judgement of others and subsequent behaviours designed to punish the 'offender' or 'teach them a lesson'. This paper outlines qualitative research that was undertaken with drivers to explore their understanding of driving etiquette and how they reacted to other drivers' observance or violation of their understanding. The aim was to develop an explanatory framework within which the relationships between driving etiquette and aggressive driving could be understood, specifically moral judgement of other drivers and punishment of their transgression of driving etiquette. Thematic analysis of focus groups (*n*=10) generated three main themes: (1) courtesy and reciprocity, and the notion of two-way responsibility, with examples of how expectations of courteous behaviour vary according to the traffic interaction; (2) acknowledgement and shared social experience: 'giving the wave'; and (3) responses to breaches of the expectations/informal rules. The themes are discussed in terms of their roles in an explanatory framework of the informal rules of etiquette and how interactions between drivers can reinforce or weaken a driver's understanding of driver etiquette and potentially lead to driving aggression.

Introduction

Considerable research has been devoted to understanding aggressive behaviour on the road. In recent research (Lennon & Watson, 2011; Lennon, Watson, Arlidge & Fraine, 2011) the authors have explored how drivers perceive their interactions with other drivers in terms of 'right' or 'wrong' behaviour, and take a moral standpoint. 'Right' or 'wrong' driving behaviour is not defined solely by legislation. In addition to the formal rules of driving, there are informal rules that are sometimes termed 'driving etiquette' (Page, Jones & King, 2013) or 'courtesy' (Hutchinson, 2008; Jonasson, 1999). These are essentially implicit behavioural norms.

Unlike formal rules, driving etiquette is *context-based*, i.e. two different settings with the same formal rules may have different forms of driving etiquette. This situation is somewhat familiar to people who drive in different cities or regions within a country, while it is more obvious to people who travel from one country to another. At the same time, interaction between individuals has a fundamentally *human* character, as described by Goffman (1963). It is notable that Goffman, in *Behavior in Public Places* (1963), specifically mentions traffic behaviour but does not unpack it in detail. The road system is a public space; it is typically developed and maintained by governments as a public good, although even toll roads involve the same degree of sharing by a wide range of individuals. Unlike most interactions between people in public places, use of the road system has a framework of formal rules, which might explain why driving etiquette has tended to receive less attention than compliance with legislation. In addition, driving a vehicle gives a degree of visual anonymity that is not shared by people who mix in public places, and constrains the range of possible interactions and communications between people. The mix of formal and informal rules, contextual and human factors, makes driving etiquette a more complex topic for study than it might first appear.

Better knowledge of driving etiquette or the informal rules held by drivers has implications for road safety and public safety. Previous studies suggest that behaviours included as part of driving etiquette may include waving when another driver allows you to merge, and the flashing of headlights as a warning signal for other drivers (Lennon & Watson, 2012). While these rules of driver etiquette are not officially recognised, breaching and/or adhering to these norms may result in moral judgements of and/or by others. This in turn may lead to irritation, frustration or anger, and to thoughts that there is a need to 'teach them a lesson' or enact retaliatory behaviours, some of which could be risky or aggressive (Lennon & Watson, 2011). At the same time, the informal nature of norm development and the many influences on norms mean that drivers may not share the same norms; moreover, a driver may espouse norms which are in contradiction with each other (Fleiter, Lennon & Watson, 2006; Fleiter & Watson, 2006). Despite the anecdotal identification of implicit norms of driving etiquette, no research has focused on specifying and defining (1) what norms are held by drivers in a given context and the level of agreement about them, and (2) drivers' attitudes and beliefs about them and their likely behavioural consequences. The relatively unformed state of knowledge in this area points to the need for exploratory research. Improved knowledge in this area may assist in reducing aggressive behaviours on road, including those that are also risky, or may inform interventions to help drivers manage the aggressive/risky driving of others (or themselves), which may benefit safety.

This paper outlines qualitative research that was undertaken with drivers to explore their understanding of driving etiquette and their perceptions of their typical reactions to other drivers' observance or violation of their implicit driving norms or rules. The aim was to develop an explanatory framework (or signposts to a framework) within which the relationships between driving etiquette and aggressive driving could be understood, specifically moral judgement of other drivers and punishment of their (perceived) transgression of driving etiquette.

Method

Participants

Participants were drawn from a convenience sample of students and employees at an urban university campus in Brisbane, Australia, along with people who had heard about the study from others associated with the university in some way. A total of 42 people (26 women, 16 men) attended one of ten focus groups that were stratified according to 'generation' based on the reasoning that different generations of drivers (e.g. 'baby boomers' versus 'generation Y') may be socialised differently, or have different implicit driving norms, attitudes and judgements. However, there did not appear to be age differences in the nature of the issues raised in the groups so the analysis was conducted on all transcripts together. Gender composition of the groups also varied, though all but one group had both men and women. The exception was the 55 years and older group, which consisted only of three women.

Procedure

Focus group discussions began with an introduction to the facilitator and the general aim of the study (that is, to explore driver experiences and learn about unwritten or informal rules of driving). Participants were asked first to think about their everyday driving experiences. The facilitator then posed the initial question: "When you think about your everyday driving, what would you say are the expectations that you have about how other drivers should behave towards others?" Probe questions then followed on from the issues and interests arising in each focus group. Once group members appeared to have said all they wished to say in relation to this first question, subsequent questions focussed on their views about whether other drivers shared the same expectations as they did, and whether they thought that there were 'unwritten' rules, and if so, what they would describe these as being. Later questions were designed to explore how drivers respond to others' breaches of their expectations or the informal rules, and whether they themselves ever breached their own rules. These later questions and probes were also aimed at teasing out driver cognitions, especially judgements of others, and their feelings in relation to perceived breaches of expectations. During the discussions, there were comments from participants about interactions with other road users such as pedestrians, cyclists and motorcyclists. Although these are important relationships in the overall issue of driving, the authors view them as likely to be sufficiently different from driver to driver relationships that they are worthy of investigation in their own right. It was beyond the scope of this study to focus on them and no specific questions were included about these. This could be an important area for future work.

Analysis

Six of the ten focus group discussions were audio recorded and transcribed in real time by a professional stenographer. Remaining discussions were audio recorded and the researcher/facilitator (AL) later made detailed notes from the recordings. The transcripts were analysed in an inductive process by one author (AL) and an independent researcher for emergent themes. Following the separate coding the researchers compared the themes identified. Although inter-rater reliability was not calculated statistically, there was a high level of agreement between the two coders on the key themes. In addition, a process of critical reflection was undertaken during the analysis in order to identify an explanatory framework within which to understand driving etiquette.

Results

With two notable exceptions, issues, and the themes that were identified in relation to them, were very similar across groups, suggesting that the expectations drivers have of others and themselves do not vary appreciably over age/generation, and so the planned analysis by age group was abandoned and all transcripts were considered together. Below, the three main themes, Courtesy, reciprocity and two-way responsibility; Acknowledgement; and Breaching etiquette are elaborated, with examples given as verbatim quotes. Gender and age group of the speaker are identified for longer quotes (in parentheses following the quote).

Theme 1: Courtesy and reciprocity, and the notion of two-way responsibility

In response to being asked about their expectations of others on the road, all groups either began by declaring they expected others would be 'courteous' towards everyone else on the road, or they rapidly converged on this theme. Participants talked about respect, good manners, and being mindful of others. There was also a dimension of reciprocation within the notion of courtesy. This was described as "give and take" (Woman 35-50) or was referred to in the same context as making allowances for others in anticipation that they would then do the same. In one group consideration of others was even linked to Australian traditional values and "a culture of mateship" (Man 25-30) and fairness. However, some participants highlighted that reciprocation and consideration was not universally held among drivers, and that some people maintained double standards: "some people expect others to be polite to them but they won't be polite to everyone else" (Woman 18-24).

While inevitably the definition of courtesy was associated with an expectation of others knowing and following the formal road rules, participants also described less formal ‘rules’ or expectations. These included that others would exercise patience with traffic circumstances such as having to wait, would be aware of the behaviour of others (especially erratic driving) and “make allowances” (Woman 25-30) for this by adjusting their own driving, or be “generous” (Woman 25-30) to others, and would avoid “…getting upset too easily” (Woman 35-50) or interpreting the behaviour of others as deliberately designed to be antagonistic or inconvenient. Interestingly, drivers in one of the 25-30 years groups suggested that being more experienced drivers placed the onus on them to be accommodating and cooperative in situations where other drivers might be less experienced.

Participants were asked whether they thought that everyone had the same expectations of others when driving. While overall, adhering to the formal rules and being courteous to others was seen as easy to do, and therefore somewhat inexplicable when drivers didn’t do this, participants also acknowledged that breaches of both formal and informal rules and expectation were evidence that people thought differently about this.

> [do others have the same expectations?] I’d say not. You’ve just got to look at the way some people drive their cars. People who are always in a rush, there’s no way that they have the expectation that ‘oh I should leave a gap. I should give people enough room’. They just don’t care. I can’t see them sharing the same expectations as someone who thinks you should be courteous. (Man 25-30)

In relation to the formal road rules, there was acknowledgement of the purpose of these while at the same time drivers also appeared to recognise that adherence depends on mutual agreement, as expressed by one driver:

> There’s a degree of trust implicit in being on the road… [that] People do what they are required to by law and also an expectation of courtesy. When that trust is breached by changing out of that safe passage, that is where accidents or incidents occur. (Man 35-50)

A question that emerges from these accounts of an informal set of rules that are shared, is how these rules are learned. The subsection below notes the influence of specific traffic situations.

Examples of expectations about behaviour

Giving way was an important feature discussed as part of expectations of others on the road. This was mentioned by each group to a greater or lesser degree. Courtesy was specifically described by one group (25-30 years) as involving giving way even when not strictly required to, if the circumstances appeared to demand this. It was seen as part of managing safety and risk: “[You have to] Llean toward minimising the risk even if it is not in the rule book, err on the side of caution” (Man 25-30) or towards “hazard reduction” (Woman 25-30) even if privately cursing under one’s breath.

Merging behaviour was a special case of the expectation of courtesy within giving way and appeared in descriptions of courtesy: “if there is like a lane that is finishing and then you let that person in kind of thing, like that's good manners” (Man 18-24). In each group, merging courtesy included this notion of merging as turn taking as well as an acknowledgement of the importance of doing this in order to help traffic flow, spread the burden of delays and display consideration:

> I always let cars in, in that situation [turning into heavy traffic], at least one. Then you expect the others behind to let in one. Quite often you are in this situation and nobody opens up to let you in. (Woman 35-50)

> When you see this in action [one for one turn taking] it actually works. (Woman 35-50)

However, there was also the 'rule' that a driver was only obliged to allow a single other to merge, as discussed by three participants in a 25-30 years old group:

> Woman 1: I think there's a certain - Like if there's a line that's been going for ages and ages and ages. And someone's [another driver] also been waiting, but not in line, hmmm, its difficult…
> Woman 2: yeah
> Man 1: yeah…difficult…
> Woman 1: It's difficult to judge [what to do]. Personally for me, if it was me, and I've been waiting in line for a while and I can see there's someone who's going to have trouble getting in, I'll well "go on then" [let them merge]
> Woman 2: Yeah. But I would say, just one though. If there's a line of people. Cos if you let one go [merge, enter the lane], often another one will try and push in and I get quite upset. 'No, no. Wait till the next guy'. You know, I've let one in. I've done my thing. That's it

Conversely, failure to facilitate such merges or "taking advantage" was seen as unnecessary discourtesy, as captured below:

> You let one person go through [in a merging or give way situation] and all of a sudden five of them go because you have been way too nice about it. Then you stop feeling okay about it and start feeling angry. (Woman 18-24)

Another informal rule appeared to be in relation to what speeds drivers should be using. While there was no apparent acceptance of illegal speeds in any of these groups, drivers spoke of their expectations that no one should drive under the speed limit either, and there were descriptions of high levels of irritation and reaction to drivers who did drive substantially under the limit (see below). Drivers also expressed that an informal rule was 'the right hand lane is for speeders' and that this was an accepted among drivers. In Australia, traffic laws in each state specify that the right hand lane be used for overtaking. Fines apply for inappropriate use if detected by police. However, these lanes are not special speed zones, and the same speed limits apply to them as to the other lanes on the same segment of road. At the same time as describing this informal rule, people in each group also acknowledged that they didn't agree that people should speed (which was not defined by participants or the facilitator). However, they also referred to a driving norm that people in the right hand or outside lane should not hold up other traffic or let other traffic build up, even if those others are driving at an illegal speed:

> There is an expectation that, if you are in the right lane, you shall exceed the speed limit. The right lane is for like 'I have got to get there'. (Woman 18-24)

> Outside lane is for speeders and overtakers - don't use it if you aren't doing that. (Man 25-30)

An informal rule that, while not universally held was mentioned by some and not censured by the others in the groups, deserves special mention for its contradiction to the other points in relation to etiquette: tailgating. Tailgating was generally described as a behaviour intended to pressure a slower driver to speed up, and was reported by drivers who appeared to be aware of this as dangerous and intimidating:

> I have done like [tailgated]– [for] people slowing down - I don't tailgate as much as other people. I do get closer. In my head I am going, 'I] need to slow down.' …Sometimes I will semi-tailgate them for the same effect: 'You are an idiot, speed up.' That makes them scared. At the same time, it is horrible if someone did that to me. Most times I back off. (Woman 18-24)

It appears that a large proportion of drivers may hold the informal rule that everyone should drive at the speed limit, rather than accepting this as the maximum speed for the road section. Failure to drive at the speed limit appears to be a sufficiently great breach of informal rules, possibly because of the potential to impede the progress of others, to justify tailgating in retaliation. As illustrated above, such drivers may have highly ambivalent feelings about tailgating, and find ways to rationalise their own behaviour while paradoxically acknowledging the negative emotional impact on the recipient as well as the physical risk.

Theme 2: Acknowledgement and shared social experience: 'giving the wave'

Waving, smiling or nodding to acknowledge another driver spontaneously arose as a key theme in all but one of the groups. Drivers described 'giving the wave' to show appreciation of another driver's consideration and had expectations that others would similarly acknowledge their considerate actions. Groups varied in their apparent perceptions of the importance of doing this, with two of the groups (an 18-24s and a 25-30s) spending quite a bit of time discussing their experiences and views about acknowledging others and being acknowledged. Participants in one of these two groups expressed relatively strong emotion in relation to this:

> The wave is so important. If someone gives me a wave, they are my best friend in the entire world. If they don't, I hate them, especially if you go out of your way…It is just etiquette. When I do that [go out of my way], I expect a wave. (Man 25-30)

Those in the other group for whom this was an especially important issue also referred to a more generalised effect. Drivers who acknowledged others were perceived as relaxed and courteous; those who failed to acknowledge the efforts of others through some form of acknowledgement were regarded as not only rude but as more likely to break the road rules or be generally uncaring about others. That is, drivers made more general attributions about the other and his or her conduct in everyday life. Participants in this group made reference to recognising that they may be stereotyping others by thinking in this way, but also thought that they would still be affected by their responses. One participant described reducing this negative effect by reminding herself that others don't really have to acknowledge her and that it is not important enough to allow it to have a big impact in the overall scheme of driving.

As well as being an informal thank you, acknowledgement appeared to have the function of creating a level of connection between drivers, an indication of shared values, and a signalling of awareness of voluntary cooperation, as well as humanising the shared experience of driving. This was expressed in a way that suggested that it enhanced the experience of driving, and acted against the depersonalising aspect of being enclosed in a vehicle and separate from others on the road:

> …it is like that kind of people connection. You can be driving around and you don't really….you are not really viewing them [other drivers] as individuals. You are viewing them as cars. You are not thinking about them as people. If someone does something, acknowledges or whatever, then you see more the person and not just the car. (Woman 55+)

'Giving the wave' was also seen as a way of being able to apologise or acknowledge to other drivers that one had made a mistake. This too was seen as facilitating inter-driver harmony and safety. Interestingly, one driver expressed the view that waving might be a peculiarly Australian behaviour and related to culture. In making this observation, the same driver related having used an acknowledgement wave while driving in the USA and thought that it had been perceived as aggressive rather than appreciative.

Theme 3: Responses to breaches of the expectations/informal rules

Breaches of the road rules or informal etiquette elicited feelings of anger and frustration for drivers in every age group. Examples of breaches included descriptions of others behaving in ways that ignored consideration for the circumstances and other drivers' patience, for instance, when attempting to circumvent the impost of congestion on all drivers by ‘queue jumping’. One driver referred to this as follows:

> [traffic is] banked up for kilometres. They will [transgressor] get in their own lane and go straight up on the inside [road shoulder]. Everybody else seems to think, ‘We are in this position, we can't do anything about it, we have got to put up with it, let's not lose it [our tempers]’, except for a couple of young kids. I looked whenever that did occur but they are all the very young, impatient P platers, [they think] ‘[I’m]fed up with this’, they get in their own lane and fly. It's totally illegal. Where is the etiquette in that? (Man 35-50)

Some drivers offered explanations of others’ breach behaviour that were based in individual characteristics such as, that others were deliberately selfish, that they didn’t care, were thoughtless in relation to driving, or that they had separate rules for themselves from those they had for others. Other explanations focussed more on skills or knowledge-based factors and regarded discourteous driving as a result of poor role models for driving, or as lack of knowledge of the formal as well as informal rules, or a failure to appreciate “the bigger picture” (Man 25-30). These explanations together may be interpreted as representing a conflict in values between drivers who approach driving more from an individualistic perspective versus those who recognise the inherent collective nature of road use and the need for cooperation. Courteous drivers accept that everyone is subject to inconvenience in order to share the road safely, rather than seeking to benefit at the expense of other road users

As described in relation to responses to acknowledgement from other drivers, there were psychological responses to the breaches of the informal rules. Participants admitted to making negative attributions of other drivers in response to these breaches, which were perceived as a violation of the expectation of reciprocation:

> I feel like ‘Why do you do that?’ kind of thing, you are putting other people in danger and you are not being nice to people who are being nice to you. If I am doing a nice thing I deserve the same gratitude back. If everyone is nice on the road, it would be a more peaceful place and you wouldn't have as many crashes and as much danger on the road. (Woman 18-24)

Drivers in the older age groups, while still admitting to frustration and anger when other breached their expectations on road, were more inclined to express motivation to “let it go” (Woman 35-50), and avoid reacting. Some drivers referred to this as a maturational process:

> As I’ve got older I have changed the way I see things and tend to look at reasons that people may be doing what they do and give benefit of doubt-it reduces stress. (Woman 35-50)

> I used to be more aggressive when I was younger but I just don’t let it [others’ behaviour] bother me now. There is no point in being frustrated anymore. (Man 35-50)

There was also evidence that inconsiderate or rude/discourteous driving was taken as a personal slight among the younger drivers, and that it indicated that the offending driver had “demeaned” the other or “diminished my status” (Man 25-30). Such breaches were sometimes perceived as being deliberate or within volitional control rather than a result of a lack of awareness or skill: “I think ‘jerk’, not ‘you are a sh** driver’” (Woman 25-30). Other younger drivers appeared to generalise the offending driver’s behaviour beyond the immediate situation:

> …if you are being this much of a bad person on the road, I would hate to tick you off…because you always hear stories about people stopping at traffic lights [and becoming confrontational]…if I was in that situation [someone becoming aggressive towards him], I would not know what to do…that is why I want to keep a bit of distance: If I tick that guy off, something bad could happen. (Man 18-24)

Breaches of informal rules were also associated with behavioural responses for some drivers. For example, some younger drivers described using the horn to indicate their frustration and anger, and described subtle distinctions in how the horn could be used, for instance blips on the horn versus blasts for different levels of frustration or transgression. These comments and accounts can be interpreted as attempts to police the informal rules or coerce compliance from other drivers.

Although the conversation around responding to breaches of informal rules suggested that in the main, drivers did not act on their thoughts or feelings in terms of their driving, there were descriptions of more problematic reactions. Several younger drivers reported adopting hostile and aggressive responses which included speeding up to get a good look at the offending driver and glaring at them, honking the horn, and deliberately driving too closely (tailgating). As already described above, tailgating was one response to drivers who were not driving at the speed limit. Some drivers in the older age groups also used other intimidatory behaviours to convey their criticism of inconsiderate driving:

> The other night someone annoyed me. I followed them and followed them. I took the next corner [after doing that] knowing it was going to make them think. It is my way of educating them….letting people know they were stupid in my opinion. (Man 35-50)

However, the earlier quote noted that "If I tick that guy off, something bad could happen" (Man 18-24), which indicates an awareness that a driver's attempt at retaliation, 'punishment', or signalling of disapproval of a perceived violation of the informal rules, could potentially escalate into more serious altercations, and potentially high risk behaviours (e.g. tailgating, pursuit, forcing off the road) or interpersonal violence.

Discussion

Our findings suggest that there are some shared understandings of how drivers should behave in situations not covered by the formal road rules. These were centred on expectations that everyone would demonstrate general respect and courtesy for other drivers, as well as expectations that everyone follow the road rules. Special instances of informal rules applied to merging behaviour and other situations where one is not obliged to give way, but consideration for others and good etiquette demands it (e.g. for long queues of cars trying to enter congested or peak hour traffic). Informal acceptance of illegal behaviour also appeared in the rule relating to the use of the right hand lane for speeding. Acknowledgement appeared to hold an important place in managing relationships with other drivers, functioning as a way of connecting with them or being rewarded for good etiquette. For some drivers it was critical to their emotional responses and presumably to their subsequent behavioural responses.

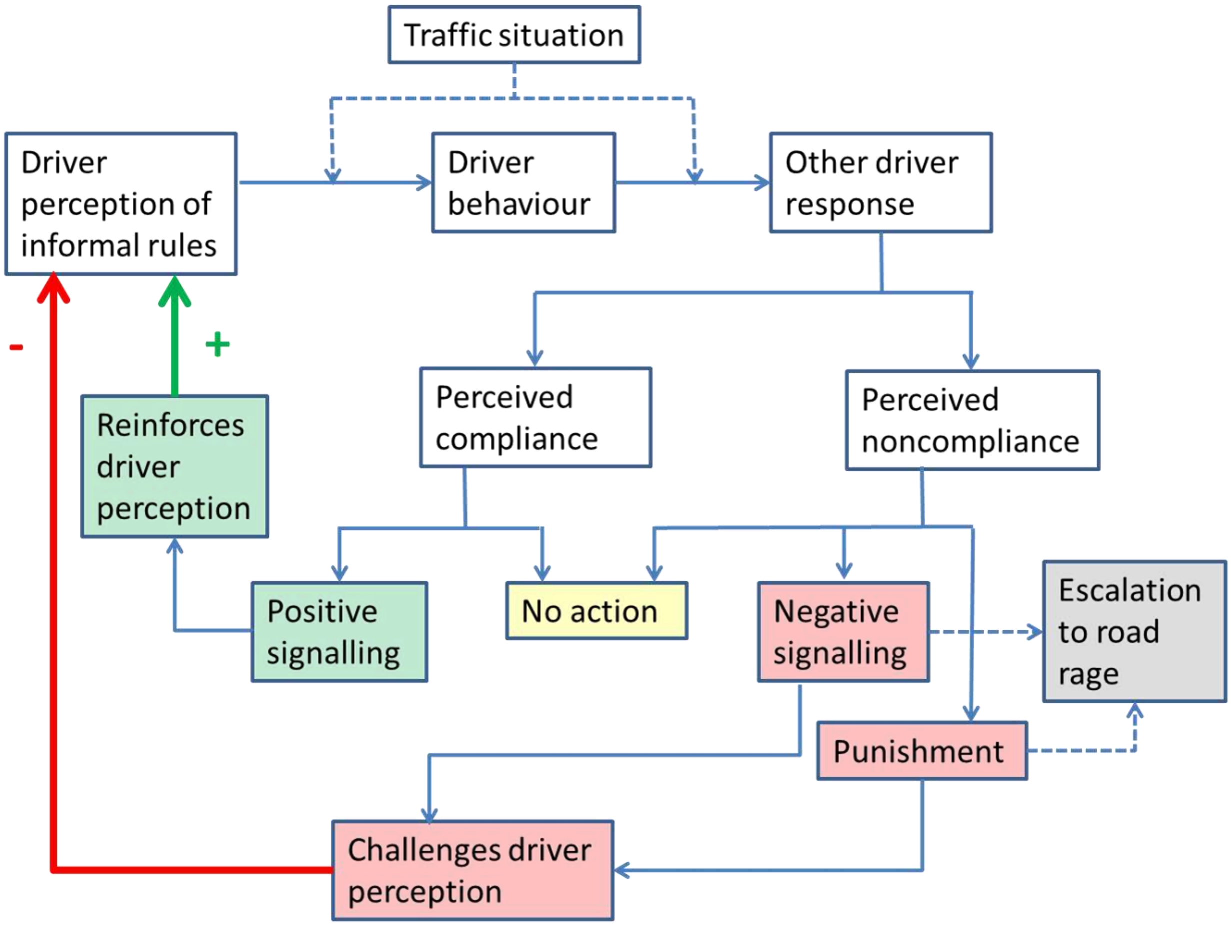
However, drivers in our study acknowledged that not all other drivers accept or adhere to the same understandings of what these informal rules are or where they apply. It may be that drivers who took breaches of informal rules as evidence that others didn't share the same understanding are correct; that is, the informal rules are not universal across drivers or driving cultures. Alternatively, drivers who breach informal rules may be fully aware of the existence of such expectations (may even hold these themselves) and simply be choosing to benefit at the expense of the group, applying the double standard referred to by some of the drivers in our study.

Driver emotional responses to breaches of the informal rules/expectations were fairly consistent across the groups: Almost all drivers were angered to greater or lesser extent. Cognitively, it appears that breaches of informal rules encourage drivers to make attributions about the 'offending' driver, and these have moral overtones. Their reports of their behavioural responses varied widely, from momentary acknowledgement of their irritation and a conscious decision to avoid allowing it to affect their mood or driving, to instances of hostile or physical aggression or intimidation.

We wish to speculate further on the meaning of the findings from our analysis of the transcripts. We propose that driving etiquette and the related driver aggression is best understood in terms of a more longstanding challenge in human interaction – sharing social space with strangers. This shares Goffman's (1963) approach to human behaviour in public places. Interestingly, in one of the few studies identified where sharing of space has been addressed in the transport setting (Mattioli, 2014, in relation to public transport), the author argues that "the car is the polar opposite of public transport, as its semi-private space allows people to avoid any interaction with strangers during travel" (Mattioli, 2014:58). Our focus group transcripts clearly indicate that this is a fundamental misperception of the nature of interaction between motorists in vehicles. As we have previously argued (Smyth and King, 2006), the driver-car assembly functions as a social being, with the vehicle being an extension of the self.

Figure 1 presents an explanatory framework for the complex of informal rules and behavioural responses that underpin driving etiquette.

Figure 1. Explanatory framework: setting, signalling, policing informal rules of driving etiquette



The basic premise behind the framework is that driving on the road involves sharing a social space. We share the road for mutual advantage in terms of mobility and to achieve a range of goals. We have formal rules which apply at all times in the same way, and should be understood by all. At the same time we need informal rules to cope with situations where the formal rules do not offer much help, such as a congested merging situation (Jonasson, 1999). It would therefore be expected that we would have evolved protocols that are informal to be used in this social space (driving etiquette), and that might be dependent on the micro-context, that need to be signalled as mutually understood, and that need to be policed informally. As a corollary, we would expect that perceived transgression and attempted policing could escalate on occasion to contested understanding, altercations between drivers, or even interpersonal violence. We can interpret statements from our participants in relation to acknowledgement and responses to breaches of informal rules as evidence of this.

As noted earlier, an interesting question relates to how the informal rules that comprise driving etiquette evolve. While the framework does not address this, it indicates how a driver's understanding of driving etiquette might be reinforced or weakened by the feedback received from other drivers. The framework assumes the informal rules are communicated between drivers through their actions, and are policed in the same way, although there are likely to be mechanisms for these purposes outside the driving situation. Another important but rarely acknowledged question relates to how drivers indicate to other drivers that they understand the requirements of driving etiquette – after all, a driver is less able to communicate with words, gestures and facial expressions than a person who is not in a car. Our respondents noted that some common physical gestures (the wave) can be used for positive communication, while the car itself affords other types of signalling for the driver-car assembly ranging from less aggressive (flash headlights, short horn operation) to more aggressive (tailgating, prolonged horn operation) actions.

This framework provides opportunities for undertaking quantitative research to explore the development and use of driving etiquette, which can provide an understanding of 'normal' driving and its relation to aggressive driving. A limitation of the study is that it relies on a moderate-sized sample and is qualitative in nature. However this is considered appropriate as a first step towards a more structured, hypothesis-driven research approach.

Conclusion

Based on an analysis of focus group transcripts aimed at understanding driving etiquette and its relation to driver interactions, we have proposed a framework to explain how drivers share the social space of the road with strangers. To achieve successful sharing, several elements are required. First, there must be some kind of protocol or etiquette about how people interact with each other. This is not arrived at by decree, because no one is in charge outside of the formal framework of legislation; instead, it evolves from interactions and emerges as a rough set of rules understood in different ways by different people. It is also dependent on the micro-context, e.g. the etiquette that applies in daytime peak traffic may not be the same as the etiquette that applies in the early hours of the morning when traffic is very light. Second, there must be a way of indicating mutual understanding of the etiquette. Third, there must be a way of policing violations of etiquette in a way which restores calm rather than escalating tension. This involves both mechanisms for indicating annoyance with a perceived transgressor and those that allow apology for 'bad manners' or mistakes, which when used, allow mutual acknowledgement that a lesson in etiquette has been learned or accepted. We recognise that the framework and our interpretation of the material in the driver discussions is somewhat speculative in nature, and we offer it as a starting point for further exploration. It may be that the value of elaborating the framework is in its application to assisting drivers to better manage their perceptions, judgements, and attributions during interactions with others, to reduce the possibility of tension or conflict between drivers, especially in non-regulated or ambiguous situations.

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Students' Responses to the RACQ Docudrama Program

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Abstract

Young people are over-represented in road crashes and school-based education programs, including the RACQ Docudrama program, represent initiatives aimed at improving road safety among this high-risk group. The aim of the study was to apply an extended Theory of Planned Behaviour framework to understand more about the extent to which the program influenced individuals' intentions to speak up to a driver engaging in risky behaviours (e.g., speeding). Senior high school students (N=260) from 5 Queensland schools completed a survey in class. The study included a Control group (n = 86) who responded to the survey prior to completing the Docudrama program and an Intervention group comprising an Intervention-Immediate (n=100) and an Intervention-Delayed group (n = 74) who completed the survey after having participated in the program either on the day or up to a week later, respectively. Overall, the findings provided support for the beneficial effects of the program. Some of the study's key findings included: (i) Intervention group participants consistently reported significantly stronger intentions to speak up than participants in the control group; (ii) among the significant predictors of intentions, a notable finding was that the more individuals anticipated feeling regretful for not having spoken up to a risky driver, the stronger their intentions were to speak up; and (iii) the level of fear reported by students significantly decreased and was lowest at the conclusion of the program, following facilitated group discussion. The implications of the results for future research, program development and practice are discussed.

***Please note that the content of this paper has been drawn from a report prepared for the RACQ. The citation of the full report is as follows:**

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Introduction

Young people are over-represented in road crashes, fatalities, and injuries, compared with other age groups. In 2013, of all states and territories in Australia, Queensland had the highest number of road deaths among road users aged 16 years and under, and the second highest number of road deaths among road users aged 17-25 years (Bureau of Infrastructure, Transport and Regional Economics [BITRE], 2014). In the attempt to reduce crash involvement of young adults, substantial resources are dedicated to road safety initiatives targeting young drivers and passengers, including road safety school-based education programs. In Australia and elsewhere, many different young driver education programs exist, including the RACQ's Docudrama program. The program runs within student classes for approximately 3 hours and, similar to some other programs, it features a mock car crash scene. This scene appears as the first of three parts in the Docudrama program.

The crash scene features audience members' fellow classmates acting as the victim, driver, and passenger in the role play. The mock crash occurs outdoors (e.g., on a school oval or assembly area) and is attended by actual emergency response teams as well as a funeral director. The deceased crash victim, “Katie” is shown to be zipped up in a body bag and taken away by the funeral director. This crash scene is followed by parts two and three of the program, both of which are classroom sessions, facilitated by RACQ staff who are trained teachers, accompanied by teachers from individual schools. These latter two parts were added as part of RACQ’s revisions to the program once they commenced running it from 2014 (i.e., the RACQ took over running of the program, running it for the first time in 2014 after the retirement of the program’s developer and long-term facilitator, Mr Barry Collis). In Part 2 of the program, students are shown the “Party Video” which depicts the 12 hours leading up to the crash. Students are guided by the facilitators to identify the risk factors evident in the video and which contributed to the crash. These risk factors incorporate particular focus on the ‘Fatal 5’ behaviours: speeding, drink driving, non-use of seatbelts, fatigue, and distraction (mobile phones) (Queensland Police Service, 2014). The third part of the program is the “Voting Session” which involves facilitated discussion. In this final session, students identify strategies that they could use to help them avoid ending up in similar, risky situations. Students are encouraged to value themselves as important, to trust their gut instinct if a situation (i.e., getting in a car with a driver) does not feel right, and to take responsibility for their own and others’ safety.

Given that the RACQ Docudrama program features a mock car crash scene, the program may be conceptualised as a fear-based approach. To the extent that fear has been recognised as an important motivator, through encouraging individuals to ‘do something’ to remove the aversive feelings of fear, the objective of fear-based approaches is not just to scare people but to promote changes in attitudes, intentions, and ultimately behaviours. Over a number of decades, however, a substantial body of research has amassed that suggests that the relationship between fear and persuasion is complex and high levels of fear do not equate to enhanced persuasion. In particular, research suggests that the fear-persuasion relationship is influenced by various factors (Lewis et al., 2007). Of these factors, theoretical (e.g., Extended Parallel Process Model [EPPM]; Witte, 1992) and empirical evidence (e.g., Lewis et al., 2010) has highlighted the particularly crucial role of providing strategies within fear-based messages in that such strategies function to enhance acceptance and reduce rejection of fear-based messages. Thus, considering the three parts of the RACQ Docudrama program, the combination of fear together with the facilitated discussions focusing on identifying risks and strategies to address such risks appears consistent with tenets of the EPPM. In particular, according to the theory, the mock car crash scene would constitute the physical threat that one should feel fearful of as a relevant and severe threat. However, the provision of strategies should function to help reduce individuals’ feelings of fear, thereby enabling them to focus on what actions they can take to reduce their risk.

As an overarching objective, the RACQ Docudrama program aims to raise young people’s awareness of risky on-road situations and to empower them to take control of their life and of situations they find themselves in to prevent them ending up in risky on-road situations. A theoretical framework that respects the important role that one’s perceptions of control over behavioural enactment have upon subsequent intentional and behaviour change is the Theory of Planned Behaviour ([TPB]; Ajzen, 1991). The TPB is a well-validated social psychology model of attitude-behaviour relations (Ajzen, 1991). The TPB maintains that its standard constructs of attitude, subjective norm, and perceived behavioural control (PBC) underpin intentions, and that intentions then predict behaviour. The TPB proposes that a person’s intention to perform a particular behaviour is the most proximal predictor of that behaviour (Ajzen, 1991). Three separate factors are proposed to influence intentions: (i) an individual’s attitudes towards the behaviour, that relates to how favourably or unfavourably one rates the target behaviour; (ii) subjective norm, that relates to the perceived pressure of important others to perform the target behaviour; and, (iii) PBC that refers to the extent to which an individual believes they have control over their ability to perform the target behaviour. The framework has shown significant and consistent explanatory and predictive utility in relation to a wide-range of social and health-related intentions and behaviours, including within traffic psychology related contexts. In regards to the latter context, and of relevance to the current project, the TPB has been applied to understand factors influencing passenger's intentions when travelling in a car with a speeding driver (Horvath et al., 2012).

The TPB's explanatory value may be enhanced with the addition of other constructs. Anticipated regret relates to the extent to which an individual anticipates that they will feel sorry, and regret, for not doing something they should (e.g., not speaking up to a speeding driver when a passenger). In this research, consistent with a key focus of the Docudrama program, there was particular focus on the role that passengers may play in preventing risky driving. Although the Docudrama program seeks to influence young people when they themselves become drivers, it also focuses upon raising awareness of the dangers of being a passenger as well as highlighting what young people can do as passengers, to reduce their risk of being in a road crash. Thus, to explore affective influences further and acknowledging that, as a passenger, a young person may feel regretful for having not spoken up to a risky driver, anticipated regret was included in the current research.

Through the application of theory, research is better able to understand the overall outcomes of a particular intervention and to gain insights into why an intervention may succeed or fail. Thus, guided by an extended TPB, the research presented herein sought to understand the effects of the Docudrama program on students' reported intentions to enact safety-related behaviours when in a vehicle as a passenger; namely, intentions to speak up to a speeding driver[1].

From the outset, it is acknowledged that when assessing the effects of the Docudrama program, it would be beneficial to establish the extent to which the program improves actual behaviour and, ultimately, reduces individuals' involvement in road trauma. However, an assessment with outcome measures of this nature was beyond the scope of the current project. Furthermore, even in instances where such investigations are attempted, there are methodological challenges associated with implementing such studies as well as the conclusions which can be drawn from the findings. For instance, there are challenges associated with being able to isolate the effects of exposure to a program from other on-going and concurrently running interventions (e.g., enforcement). In addition, in instances where a study may focus on exploring program participants' subsequent traffic infringements and crash involvement, such a focus limits understanding of program effects only to instances where negative outcomes occurred and were detected, rather than understanding about instances where a young person chose the right/safe option (Watson, 2003; Williams, 2006).

The Current Research: Objective and Aims

The overarching objective of the current research was to use a theoretically-guided investigation to understand the effects of the Docudrama program upon students. Specifically, the aims of this research presented herein were to:

1) Determine the extent to which exposure to the Docudrama program was associated with positive effects on students' reported intentions to speak up to a speeding driver. Specifically,

[1] The overall research project included assessment of a large number of intentions and willingness measures in regards to a range of risky, on-road behaviours (as well as intentions and willingness measures in regards to situations where one was said to be a passenger and a driver); however, space prohibits discussion of all of these measures herein. As some examples of the willingness measures, however, participants were asked to report, in regards to the question stem of "If, in the next month, you are a PASSENGER in a car being driven by a FRIEND, how willing would you be to.. [tell a friend who is speeding to slow down/tell a friend to stop using a mobile phone while driving/tell a friend they're too drunk to drive/tell a friend who is not wearing a seat belt to buckle up/tell a friend that they're too tired to drive]?".

   a. Determine the extent to which such intentions were higher in the Intervention groups than the Control group; and
   b. Determine the extent to which such intentions would vary over time and, in particular, whether the effects of the Docudrama program remained approximately one week after program participation.
2) Identify factors that predict individuals' intentions to speak up to a driver who is speeding and, thus, provide insight into how the Docudrama program may be influencing intentions.
3) Determine whether students' (in the Intervention group) level of self-reported fear decreased across the running of the Docudrama program. Specifically, it was anticipated that, based on predictions by the fear-persuasion model, the EPPM (Witte, 1992), the highest level of fear would likely be reported in association with Part 1 (i.e., "Car crash scene") but, that the level of fear should decrease across the subsequent two sessions and by the final session, given the focus on strategies, the level of fear should be lowest.

Method

University ethics approval was gained and then approvals were sought from the Department of Education, Training, and Employment (DETE) for the state high schools as well as from the Catholic Education and Independent schools. Unfortunately, approval from the DETE was not secured in time and therefore no state schools were able to be approached to participate. Thus, of the 15 schools within the potential data collection period, only 5 schools could be approached. Of these 5 schools, permission was sought from Principals, all of whom agreed to participate.

In the between groups design, schools were allocated to one of the following groups: (i) Control, (ii) Intervention-Immediate, or (iii) Intervention-Delayed. Thus, each school only participated at one time point each and therefore any conclusions are based on *differences* between groups as opposed to *changes* in individuals' responses over time. The inclusion of the Control group provided a baseline measure with which to consider the Intervention scores, relative to no exposure at all.

One of the 5 schools had never previously hosted the Docudrama program and therefore, it was chosen to represent the Control group. The remaining schools were assigned to the Intervention group. The Intervention group was further divided into the Intervention-Immediate and Intervention-Delayed groups and two of the four schools were each allocated to these conditions. The Intervention-Immediate group participated in the study immediately after exposure to the Docudrama program; while the Intervention-Delayed group participated approximately one week after having been exposed to the Docudrama program.

Participants

Year 11 and 12 students from five central and south-east Queensland high schools hosting the Docudrama program participated. No other selection criteria were applied, although parent/guardian and student consent was required to participate. Parents/guardians were asked to sign and return consent forms to approve of their child's participation. These forms were disseminated to parents several days in advance of the researchers attending a particular school and were collected on the day that the researchers were on-site to administer the survey. In regards to obtaining consent from the students who participated, they were informed that return of a completed survey to the researchers would be taken as their having provided their consent. As an additional check that parent/guardian consent had been obtained, the student participants were asked to tick a box at the commencement of the survey to confirm that their parent/guardian had consented for them to participate. A total of 270 surveys were collected. Two students did not indicate that they had parental consent and $n = 8$ had completed less than 50% of the survey, resulting in the exclusion of

10 surveys. Thus, *N* = 260 students (*n* = 182 females, *n* = 78 males) provided useable data. Of these students, *n* = 53 (20.4%) reported that they did not have a licence, *n* = 149 (57.3%) had a Learner's Permit, *n* = 57 (21.9%) had a Provisional 1 (Red) licence, and *n* = 1 (0.4%) had a Provisional 2 (Green) licence. The students' ages ranged from 15 to 18 years. Of the 260 participants, *n* = 174 (*n* = 39 males and *n* = 135 females) were in the Intervention group (with *n* = 100 in the Intervention-Immediate and *n* = 74 in the Intervention-Delayed) and *n* = 86 (*n* = 39 males and *n* = 47 females) were in the Control group.

Measures

The measures relevant to this paper were assessed in relation to the following context, "You are a passenger in a car being driven by your friend" and the friend was said to be speeding. Wording of TPB items was in accordance with convention (Ajzen, 1991), the measure of fear was from Witte (1994), and anticipated regret was adapted from Abraham and Sheeran (2003). All items, as shown in Table 1, were assessed on 5-point Likert scales with higher scores indicating more of the construct. The only exception was for the attitude measure that was based on a 5-point semantic differential scale. Participants' responses to the perceived fear measure were assessed three times, once in relation to each of the three parts of the program.

Table 1. Summary of items used to measure the study's key constructs and the scale reliabilities.

Construct	**Items**	**Alpha/r**
Attitude	"Telling a friend who is speeding to slow down would be…" "Uncomfortable/Comfortable", "Bad/Good", "Irresponsible/ Responsible", "Unwise/Wise"	α = 74
Subjective norm	"Most people important to me would want me to tell a friend to slow down if they were speeding", "Most people important to me would approve of me telling a friend who was speeding to slow down"	$r = .44$, $p<. 001$
PBC	"I am confident that I could tell a friend to slow down", "I have complete control over whether or not I tell a friend to slow down if they were speeding", "It would be easy for me to tell a friend who was speeding to slow down"	α = 77
Anticipated Regret	"I would feel sorry for not telling a friend who was speeding to slow down", "Not telling a friend to slow down when they are speeding is something that I would regret"	$r = .58$, $p<.001$
Intentions	"I intend to tell a friend who is speeding to slow down", "I plan to tell a friend to slow down if they are speeding", "I would be willing to tell a friend who is speeding to slow down"	α = 85
Fear	"To what extent did you feel anxious/sad/fearful"	α = .91

Procedure

Students completed a hard copy questionnaire that took approximately 25 minutes. It was completed in school time, in classroom groups in the presence of teachers, together with two members of the CARRS-Q research team[2]. In each school, students who participated were entered into a random draw for one of five $20 iTunes vouchers.

[2] There was only one exception to this approach whereby CARRS-Q researchers were unable to be on-site due to distance. In this instance, arrangements were made with the RACQ staff, who were on-site to deliver the Docudrama program, for them to collect the surveys and return them to the CARRS-Q team.

Results

Intervention versus Control groups on intention measures

To compare differences in mean intention scores to tell a driver to slow down between the Control, the Intervention-Immediate, and Intervention-Delayed groups, an ANOVA was conducted. As Table 2 shows, an overall significant group difference was found. Follow-up pairwise comparisons revealed that participants in both the Intervention-Immediate and Intervention-Delayed groups reported significantly greater intentions than Control group participants. Further, the two Intervention groups' mean scores did not significantly differ from each other.

Table 2. Descriptive scores and ANOVA results for differences between groups on intentions.

Dependent variable	Control *M (SD)* *n*=87	Intervention-Immediate *M (SD)* *n=100*	Intervention-Delay *M (SD)* *n=75*	*F*	η_p^2
Intention to tell a speeding driver to slow down	3.60 (0.93)	4.25 (0.84)	4.11 (0.83)	14.00***	.10

Items were measured on 5-point scales with higher scores indicating more of the construct.
****p<.001.*

Extended TPB predictors of intentions to speak up to a speeding driver

To determine the predictors of intentions to tell a driver to slow down, hierarchical regressions were conducted. Separate regressions were run for the Intervention and Control groups so as to provide an understanding of factors that were influencing students' reported intentions as a function of whether or not they had been exposed to the Docudrama program. The predictors in the regression models were drawn from the extended TPB with the TPB's standard constructs of attitude, subjective norm, and PBC added in the first step and anticipated regret added in the second step. Anticipated regret was added in the second step so as to determine the extent to which it added variance explained in intentions, over and above the variance explained by the standard constructs.

Table 3 provides the descriptive statistics of, and correlations between, the study's predictors and outcome measures of intentions to tell a speeding driver to slow down. As anticipated, all predictors were positively and significantly correlated with intentions with the only exception being the correlation between anticipated regret and PBC in the Control group.

Table 4 summarises the results of the regression analyses predicting intentions to tell a friend who is speeding to slow down in regards to the final step (Step 2) of the model. As noted previously, each regression was run separately for the Intervention and Control groups. At Step 1, in regards to the Intervention group, the standard TPB constructs accounted for a significant 44.2 % of the variance in intentions, $F(3, 162) = 42.76$, p <.001. Of the predictors, both subjective norm (β = .17, p =. 009) and PBC (β = .457, p <. 001) were significant, positive predictors; however, attitude was not a significant predictor (β = .01, p = .85). As Table 4 shows, at Step 2, the overall model accounted for a significant 48.1% of the variance in intentions, $F(4, 161) = 37.28$, p <.001. Anticipated regret added a further significant 3.9% of the variance explained in intentions, $\Delta F(1, 161) = 12.08$, p <.001. Of the standard TPB constructs, only PBC was a significant, positive predictor (β = .48, p < .001), with subjective norm no longer significant (β = .10, p = .119), and attitude remaining not significant (β = .01, p = .877). The additional predictor of anticipated regret was a significant, positive predictor (β = .24, p = .001).

In regards to the Control group, at Step 1, the standard TPB constructs accounted for a significant 24.8 % of the variance in intentions, F(3, 80) = 8.82, p <.001. Of the predictors, only attitude was found to be a significant, positive predictor (β = .37, p = .001) with neither subjective norm (β = .19, p =. 096) nor PBC (β = .06, p =. 556) reaching significance. At Step 2, as Table 4 shows, the model accounted for a significant 47.1% of the variance in intentions, F(4, 79) = 17.60, p <.001. Anticipated regret added a further significant 2.3% of the variance explained, ΔF(1, 79) = 17.60, p <.001. Of the standard TPB constructs, only attitude was a significant predictor (β = .26, p = .006) while subjective norm (β = .11, p = .227) and PBC (β = .09, p = .354) did not significantly predict intentions. Anticipated regret was a significant, positive predictor (β = .50, p < .001).

Differences between the level of fear reported over the 3 parts of the program

A repeated measures ANOVA was conducted to compare the level of fear reported by students over the three parts of the Docudrama program. The results indicated that there was a significant difference in reported fear levels across the three parts of the program, F(2, 168) = 76.49, p < .001, η^2_p = .48. Pairwise comparisons (with adjusted alpha of .01) revealed that fear reported at Part 1 (M = 3.15, SD = 1.24) was significantly higher than fear reported at Parts 2 (M = 2.54, SD=1.22) and Part 3 (M = 1.91, SD = 1.15), and that the level reported at Part 2 was significantly higher than fear at Part 3. Thus, the significantly lowest level of fear reported was for Part 3 of the program.

Discussion

Overall, the findings of this study provide evidence of there being positive effects associated with students' exposure to the RACQ Docudrama program. In regards to intentions to speak up as a passenger to a driver who is speeding, the Intervention groups were associated with higher mean scores than the Control group, while the Intervention-Immediate and Intervention-Delayed groups did not to significantly differ from each other. These findings suggest that exposure to the program is associated with positive impacts and that these effects remain up to at least one week after exposure to the program.

The extended TPB underpinning this research assisted in identifying factors influencing intentions to speak up. Although beyond the scope of the current study to incorporate behavioural outcome measures, evidence supports that, intentions, although not perfect predictors of behaviour, are the most proximal determinants of behaviour. Overall, in terms of predictors, a key finding was the support for the Docudrama program's revisions of the inclusion of facilitated discussion to heighten the focus on strategies and on students taking control of their own and others' safety. Specifically, a construct found to predict intentions in the Intervention group, but not the Control group, was perceived behavioural control (PBC). PBC refers to the extent to which one considers that they have control over whether or not they perform a particular behaviour (such as speaking up to a speeding driver) and the extent to which they consider such a behaviour as easy to perform. This finding is important because, according to the TPB, PBC may influence behaviour not only indirectly through intentions but also may influence behaviour directly. Therefore, by potentially bolstering one's perceptions of control over being able to speak up to a driver who is speeding, it is possible that this factor may directly influence one's enactment of the actual behaviour in the future, should they find themselves in a vehicle being driven by a friend who is speeding.

The influence of anticipated regret is both noteworthy and significant. This construct significantly predicted intentions for participants in the Intervention and the Control groups. This finding suggests that, for young people, anticipating they will feel remorseful and guilty if they were not to speak up to a driver engaging in a risky behaviour was an important predictor of intentions. These findings highlight the potential benefits that education programs, and advertising messages more generally, may garner from focusing on the role of peer passengers. In particular, the benefits of bolstering: (i) individual's perceptions that, as a passenger, they have the ability to speak up to a driver whom they do not feel safe travelling with; and (ii) individuals' acknowledgement of the possibility that if they do not speak up, they may feel regretful and remorseful for having not taken control of the situation and looked out for their own as well as others' safety. There may be benefit in discussing this aspect in more detail in the Docudrama program, for instance, by taking the opportunity in the discussion sessions to pose to students, "how do you think you would feel if you were to know that you could have been the one to make a difference?". Such discussion may heighten awareness of the negative affective responses that may be experienced if one does not speak up and how such affect may be remedied easily by taking action and speaking up.

Table 3. Descriptive statistics of, and correlations between, the study's variables for the Intervention and Control groups.

Variables	**Intervention group (n = 166)**							**Control group (n = 84)**						
	M	**SD**	**1**	**2**	**3**	**4**	**5**	**M**	**SD**	**1**	**2**	**3**	**4**	**5**
Intentions	4.18	0.84	-	.36***	.40***	.65***	.53***	3.60	0.92	-	.45***	.36***	.23*	.60***
Attitude	4.44	0.68		-	.35***	.49***	.30***	4.30	0.64		-	.38***	.24*	.27**
Subjective Norm	4.51	0.69			-	.38***	.44***	4.20	0.83			-	.43***	.23*
PBC	4.16	0.83				-	.50***	4.00	0.76				-	.08
Anticipated regret	3.82	1.00					-	3.06	1.10					-

Items measured on 5 point scales with higher scores indicating more of the construct. PBC = Perceived behavioural control. *p<.05, **p<.01, ***p < .001.

Table 4. Regression Analyses predicting Intentions to tell a friend who is speeding to slow down: Results for the Intervention and Control groups.

Variable	***Intervention group***				***Control group***			
	R^2	ΔR^2	β	sr^2	R^2	ΔR^2	β	sr^2
Step 2	.481***	.039***			.471***	.223***		
Attitudes			.01	<.001			.26*	.05
Subjective Norm			.10	.007			.11	<.01
PBC			.48***	.141			.09	<.01
Anticipated Regret			.24**	.038			.50***	.22

Items were measured on 5 point scales with higher scores indicating more of the construct. PBC = perceived behavioural control.*p < .05, **p < .01, ***p < .001.

Further support for the RACQ Docudrama program was offered through the finding that self-reported levels of fear experienced by students in the Intervention group decreased over the three parts of the program. Specifically, the results supported expectations with reported levels of fear highest at Part 1 ("Mock Car Crash Scene") and significantly decreasing over each subsequent Part of the program, with Part 3 ("Voting Session") associated with the lowest level of reported fear. Finding a statistically significant pattern of decreasing levels of self-reported fear in accordance with the ordering of the program's content does support such ordering and, in particular, further supports the important role that the facilitated discussion may be playing in bolstering awareness of, and confidence in, strategies for reducing risk and also in reducing fear. Theoretically, the EPPM and fear-relief models suggest that fear alone is insufficient to motivate desirable change and that evoking strong levels of fear in the absence of strategy provision is likely to lead to defensive avoidance reactions and message rejection (Lewis et al., 2010; Witte, 1992).

Strengths and limitations

This study is the first to examine the effects of exposure to the RACQ Docudrama program on young people's (i.e., Queensland high school students') intentions to speak up to a speeding driver. A notable strength of the study is the inclusion of a Control group that allowed comparison of responses between groups of students exposed and not exposed to the program. This design allowed an exploration of whether there were any discernible effects of participating in the Docudrama program, and in doing so, addresses a limitation of prior studies which have tested the effects of school-based road safety programs (see Senserrick et al., 2009). The study was strengthened by the use of an empirically tested and relevant theoretical framework that assisted with the identification of factors which influenced intentions.

Strengths notwithstanding, limitations also need to be acknowledged. A total of 15 schools were identified as falling within the potential data collection period; however, a delay in receiving DETE approval meant that state schools could not be invited to participate and, thus ultimately, only five schools participated. However, the study comprised a large sample of high school students as participants (N = 260), and was based on the inclusion of five different schools (Catholic and Independent) from around Central and South-East Queensland. Thus, it could be conceived that the final sample still would be reasonably diverse. It is also noted that, due to the inclusion of an all-girl high school without an all-boy high school available in the testing time-frame to better balance the gender ratio, the Intervention group was predominately comprised of females. Based on the body of evidence that suggests that females, generally, are more receptive to high school driver education programs, this gender imbalance has the potential to influence the study results by increasing the intervention groups' scores (Harré et al., 1996; Harré & Field, 1998; Hover et al., 2000; O'Brien et al., 2002; Powney et al., 1995).

A further limitation relates to the between groups design, in that it restricts the analysis to exploring the *differences* between students who had experienced the Docudrama program (Intervention group) and those not yet been exposed to the program (Control group). An alternative approach would be to investigate, among students exposed to the Docudrama program, the change in individual student's responses over time via a repeated measures design. It should also be noted that the potential for confounding effects of prior road safety knowledge and experience gained through driving exposure and participation in other school-based road safety education programs also exists. Including a Control group was intended to minimise this effect, however, the possibility of a confounding influence cannot be disregarded. In addition, even in instances where a repeated measures design was to be implemented, a Control group would still be essential to assist in determining whether the program had been associated with any discernible effects, relative to no exposure at all. It also needs to be noted that repeated measures designs are associated with their own limitations including, for instance, that the act of repeatedly administering a survey instrument to participants may lead to the survey itself being part of the intervention and influencing behaviour; a phenomenon referred to as the mere measurement effect (Morwitz, Stern, & Fitzsimons, 2004). In the current study, acknowledging that participating schools had already given so graciously of their time to invite the research team into classes to survey students, to have required more than one data collection period would have represented further imposition. In addition, the use of self-report measures also has the potential to introduce a source of bias in the study results. For example, it is possible that students may have overestimated their intentions to tell a speeding driver to slow down, to the extent that this behaviour could be considered socially desirable. However, the anonymous nature of the survey may have minimised this effect. Finally, it is important to note that the outcome measure of focus in this study was intentions as opposed to behaviour and that, although there was an Intervention-Delayed group, intentions were assessed at a relatively short time after exposure to the program (i.e., approximately one week later). Although intentions are the most proximal determinant of behaviour (Ajzen, 1991) evidence suggests that there is not perfect correspondence between intentions and behaviour. In addition, future research is required to determine the extent to which the findings may emerge in the longer term.

Concluding comments

The current paper presents on some of the key findings emerging from a larger study designed to assess high school students' responses to the RACQ Docudrama program. The results presented herein provide support of the positive effects of the program on students' reported intentions to speak up to a driver who is speeding. The findings also identified key factors that are influencing such intentions. In particular, an important role of PBC was identified in regards to the program potentially bolstering individuals' perceptions of control over their ability to speak up to a speeding driver. Also identified was the important role of anticipated regret for young people, highlighting that interventions which harness the power of passengers and encourage them to speak up, may be an important means to reduce risky driving among young adults. Given the extent to which young adults constitute high risk road users, it is important that interventions which encourage safer on-road related attitudes and behaviours be identified. This research has assisted with that important goal in relation to providing insights into the effects of the RACQ Docudrama program.

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Low severity rear impact simulations with average male and female dummy models in Euro NCAP test configuration

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Abstract

Rear impacts often cause soft tissue neck injuries, also referred to as whiplash injuries, which can lead to long term suffering. These injuries account for more than 60% of the costs of all injuries leading to permanent medical impairment for the insurance companies with respect to injuries sustained in vehicle crashes. Injury statistics have shown that females are subject to a higher risk of sustaining this type of injury than males and that recently developed anti-whiplash systems protect females less than males. In this study, simulations were run with both an average male and a recently developed average female dummy model seated in a vehicle seat. The three crash pulse severities of the Euro NCAP low severity rear impact test were applied. The motion of the neck, head and upper torso were analysed in addition to the accelerations and neck injury criterion, NIC.

Simulations with the male and the female dummy models showed differences related to both the crash severity and between the two dummies in a particular crash severity. For all three pulses the NIC values were higher for the EvaRID dummy than for the BioRID. The results of the study highlight the need for an extended test matrix. The inclusion of an average female dummy model would provide seat developers with an additional tool to ensure good whiplash protection also for female occupants.

Introduction

Whiplash Associated Disorders (WADs), also referred to as whiplash injuries, sustained in vehicle crashes is a worldwide problem. Estimates for the European Union, based on (Kullgren et al. 2007), indicate that 300 000 European Union citizens suffer whiplash injuries annually, of which 15 000 result in long term suffering and an associated socio-economic impact of approximately EUR 10 billion per annum (EEVC 2005). The US insurance research council reported that neck sprains or strains cost USD 8.8 billion annually representing up to 25% of the total expense for all crash injuries (US IRC 2008). In Sweden, such injuries account for ~70% of all injuries leading to disability due to vehicle crashes (Kullgren et al. 2007). The majority of victims experiencing initial neck symptoms recover within a few weeks or months of the crash (The Whiplash Commission 2005), however, 5–10% of individuals experience different levels of medically classified permanent disabilities (Nygren 1983; Krafft 1998; The Whiplash Commission 2005). Whiplash injuries occur at relatively low velocity changes (typically <25 km/h) (Eichberger et al. 1996; Kullgren et al. 2003), and in impacts from all directions, although rear impacts are most frequently featured in accident statistics (Watanabe et al. 2000).

Injury statistics from the mid-1960s until today show that females have a higher risk of sustaining whiplash injuries than males, ranging from 1.5 to 3 times higher (Kihlberg 1969;

O'Neill et al. 1972; Otremski et al. 1989; Morris & Thomas 1996; Dolinis 1997; Temming & Zobel 1998; Richter et al. 2000; Chapline et al. 2000; Krafft et al. 2003; Jakobsson et al. 2004; Strovik et al. 2009). In fact, concepts for whiplash protection seats have proved to be more effective for males than females (Kullgren & Krafft 2010 and Kullgren et al. 2013). These results suggest that the safety performance of different seat concepts may vary when occupied by males and females. It is important to further evaluate and understand the reasons behind such differences, in order to provide better protection for both genders, and females in particular.

Crash test dummies are used when developing and evaluating occupant protection performance of a vehicle. Today, females are not well represented, as the 50th percentile male crash test dummies currently used in low velocity rear impacts (Euro NCAP 2014), the Biofidelic Rear Impact Dummy (BioRID) correspond to a ~ 90th–95th percentile female with regards to stature and mass (Welsh & Lenard 2001). Consequently, current seats and whiplash protection systems are primarily adapted to the 50th percentile male without consideration for female properties, despite a higher whiplash injury risk in females. Recently, the world first numerical crash test dummy of an average female, EvaRID (Eva – female / RID – Rear Impact Dummy), was developed (Linder et al. 2013, Carlsson et al. 2014). Since its introduction to the market, mathematical crash simulations can now be performed with both an average male and an average female model.

The aim of this study was to perform mathematical simulations with both an average male and an average female dummy model seated in a vehicle seat concept model in order to quantify how the dummies responded to the same test configuration in a low severity crash in terms of loading related to risk of soft tissue neck injuries. This was done by applying the three crash pulse severities of the Euro NCAP low severity rear impact test. In order to capture the loading on the neck, the motion of the neck, head and upper torso was analysed in addition to the accelerations and Neck Injury Criteria (NIC).

Method

Simulations were run using the finite element code LS-DYNA MPP R7.1.1 (LSTC, Livermore, CA). Two finite element anthropomorphic test device (FE-ATD) models for rear impact testing were used in this study. The models were the average sized male BioRID IIg version 3.6 (licence from DYNAMore) and the average sized female EvaRID version 1.1.1 (licence from Humanetics). These models will be referred to as *FE-BioRID* and *EvaRID* respectively. The FE-BioRID consists of about 185 000 nodes and 230 000 elements with a total mass of 77.4 kg, and the EvaRID consists of about 150 000 nodes and 190 000 elements with a total mass of 62.3 kg.

The x-acceleration, angular displacement and x-displacement of the head, T1 vertebra and the relative distance between the head and T1 were analysed. The data was processed in accordance to the SAE J-211 (SAE 2003), i.e. the head x-acceleration channel was sampled at 10 kHz and filtered using an SAE CFC 180 and the remaining channels were sampled at 10 kHz and filtered using an SAE CFC 60. The X-direction of the acceleration and displacement corresponded to the horizontal direction.

In addition, the NIC (Boström et al. 2000) was calculated using the relative head to T1 accelerations, in accordance with Eq.1 and the maximum thereof (NIC_{max}), before the Head Restraint Contact (HRC) ended. The unit for NIC is m^2/s^2.

$$\boldsymbol{NIC(t) = 0.2 * a_x^{rel}(t) + \left[v_x^{rel}(t)\right]^2} \quad \textit{\textbf{(Equation 1)}}$$

The FE-ATD models were seated in one car seat concept model. The seat concept model were built from components of a commercial car seat from the 1990th with a fix head restraint. The seat was attached to a sled with an adjustable toe-board customised to the height specifications of a pre-defined heel-point. The sled assembly was subjected to three acceleration pulses with three severity ratings required by the Euro NCAP whiplash testing protocol (Euro NCAP, 2014, Figure 1). The Low pulse (LP), Medium pulse (MP) and High pulse (HP).

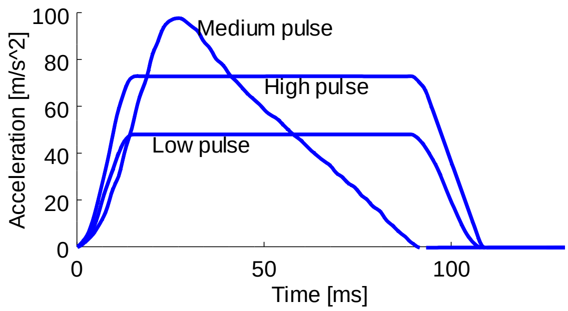

Figure 1. The three pulses of the Euro NCAP whiplash protocol that the FE-BioRID and the EvaRID were subjected to in the simulations.

The postures of the FE-ATDs were in accordance with the Euro NCAP protocol seating procedures and the design angles of the pelvis (26.5 degrees) and head (0 degrees, horizontal) were used. The models were seated by forcing the FE-models hip point (h-point) to match the pre-defined reference point of the seat (r-point), using a prescribed motion in a pre-simulation which resulted in individually deformed seats to be used for the FE-BioRID and the EvaRID models. Lastly, before initiating the simulations, a three point seat belt was added.

Using identical r-points resulted in a head-to-head restraint distance of 38 mm and a height of the FE-BioRID of 40 mm above the head restraint. The corresponding measurements for the EvaRID was a 58 mm distance to the head restraint and 30 mm below the top of the head restraint (Figure 2).

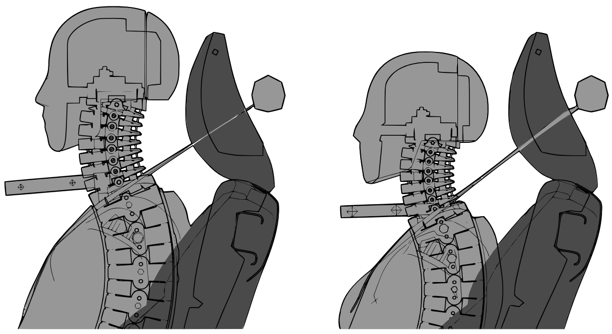

Figure 2. The initial head-to-head restraint distances of the FE-BioRID (left) and the EvaRID (right) models, when identical seat r-points were used.

Results

The simulations with the average male and female dummy models showed differences related to both the crash severity and between the two dummy models in a particular crash severity. For all three pulse severities the NIC values were higher in the EvaRID than in the FE-BioRID (Table 1).

Table 1. Maximum NIC values for the FE-BioRID and the EvaRID model and the timing of the maximum NIC value for all three crash pulse severities, LP, MP and HP.

		NIC	
Euro NCAP pulse severity	**Model**	**Maximum (m^2/s^2)**	**Timing (ms)**
Low (LP)	FE-BioRID	9.5	68
	EvaRID	12.8	77
Medium (MP)	FE-BioRID	14.2	65
	EvaRID	17.5	67
High (HP)	FE-BioRID	12.9	63
	EvaRID	16.0	66

The acceleration and kinematics results showed higher peak x-accelerations for the EvaRID, with a shorter duration compared to the FE-BioRID for all crash pulse severities. Although the EvaRID head and T1 angular displacements were lower, they resulted in a higher relative angular displacement than that of the FE-BioRID. A positive angular displacement corresponded to extension motion. The x-displacements of the head, T1 and the relative displacements thereof were less for the EvaRID than for the FE-BioRID.

The EvaRID made contact with the head rest earlier than the FE-BioRID and the difference in contact time between the dummies increased with increased crash pulse severity. The result from each crash pulse severity is shown in Figure 3, 4 and 5.

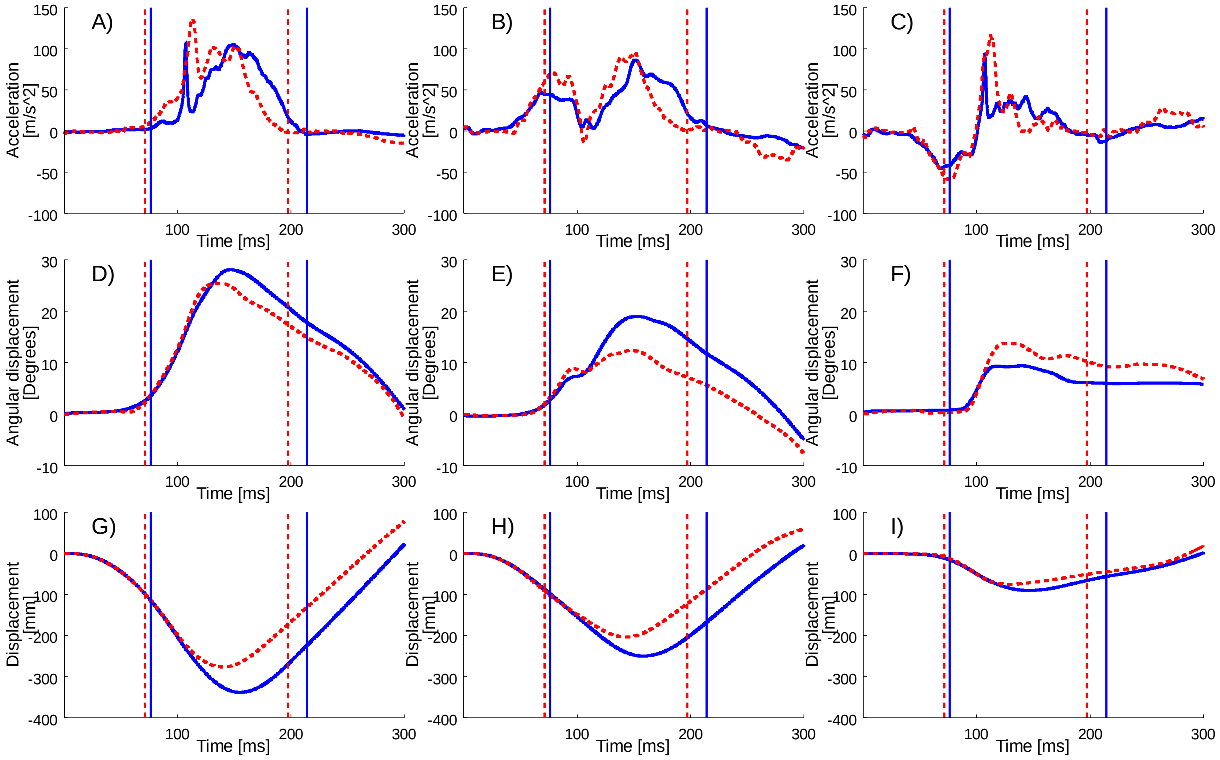

Figure 3. X-acceleration, angular displacements and x-displacements of the head (figures A, D and G), T1 (figures B, E and H) and the head relative to the T1 (figures C, F and I) for the LP Euro NCAP crash severity. Vertical lines shows the start and end of the head rest contact. EvaRID (red dotted lines) FE BioRID (blue solid lines).

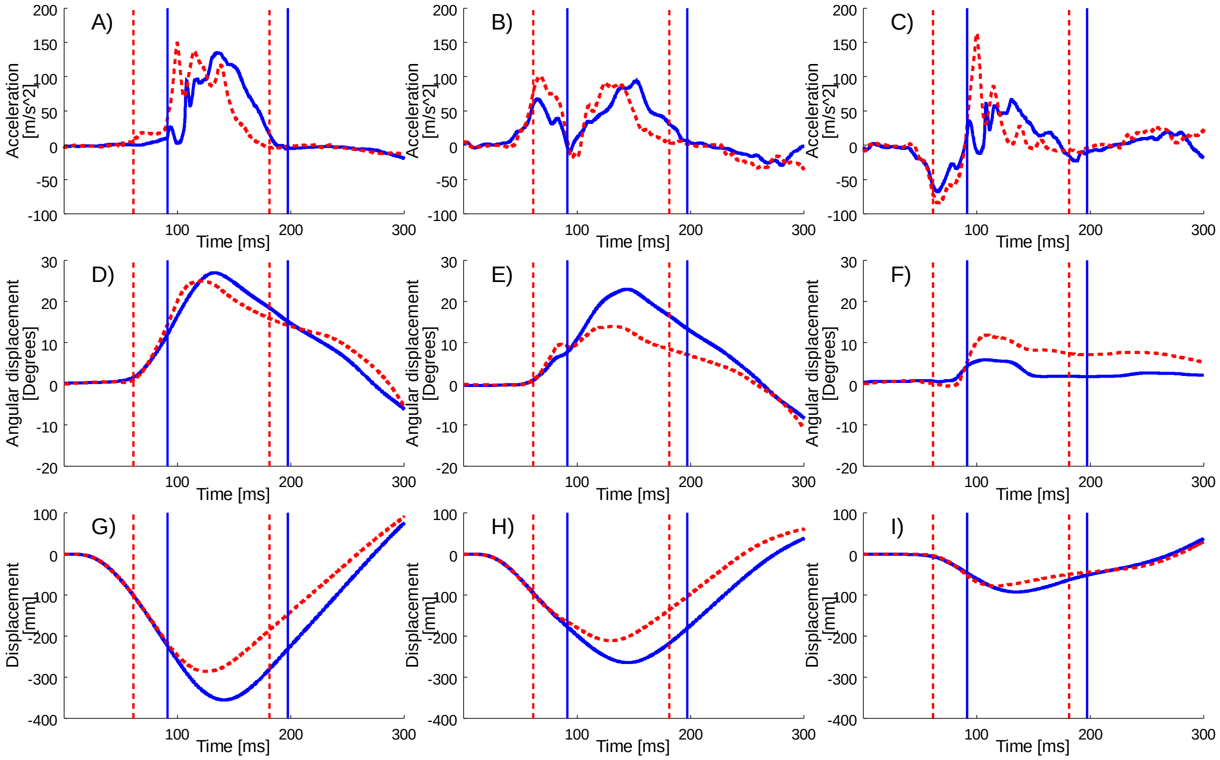

Figure 4. X-acceleration, angular displacements and x-displacements of the head (Figures A, D and G), T1 (Figures B, E and H) and the head relative to the T1 (Figures C, F and I) for the MP Euro NCAP crash severity. Vertical lines shows the start and end of the head rest contact. EvaRID (red dotted lines) FE BioRID (blue solid lines).

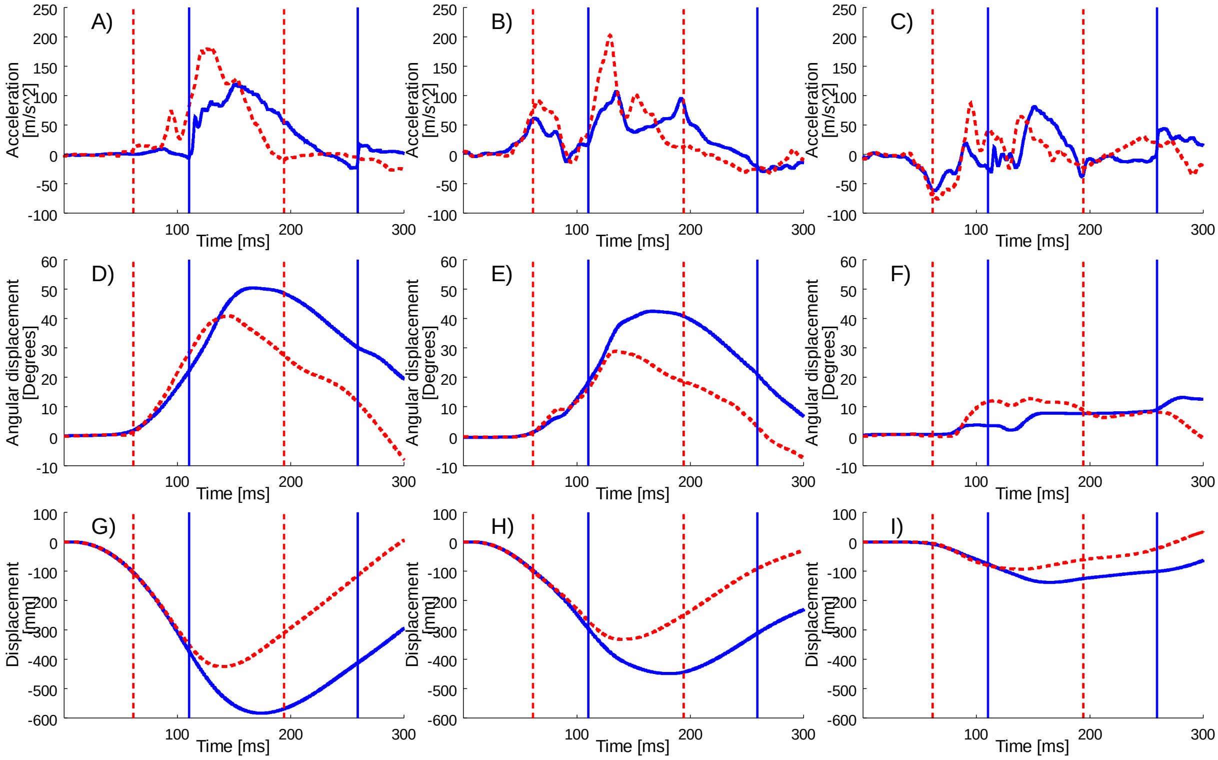

Figure 5. X-acceleration, angular displacements and x-displacements of the head (Figures A, D and G), T1 (Figures B, E and H) and the head relative to the T1 (Figures C, F and I) for the HP Euro NCAP crash severity. Vertical lines shows the start and end of the head rest contact. EvaRID (red dotted lines) FE BioRID (blue solid lines).

The HR contact time for the EvaRID was 5 ms earlier than for the FE-BioRID in the LP, 30 ms earlier for the MP and 50 ms earlier for the HP. The maximum head relative to T1 angular displacement and the horizontal head relative to T1 displacement the peak values for the EvaRID and FE-BioRID are shown in Table 2.

Table 2. Maximum head relative to T1 angular displacement and the horizontal head relative to T1 displacement values for the FE-BioRID and the EvaRID model and the timing of the maximum values for all three crash pulse severities, LP, MP and HP.

Euro NCAP pulse severity	Model	Head rel. T1 Angle Maximum (angle)	Head rel. T1 Angle Timing (ms)	Head rel. T1 Displacement Maximum (mm)	Head rel. T1 Displacement Timing (ms)
Low (LP)	FE-BioRID	9	140	75	145
	EvaRID	14	125	90	129
Medium (MP)	FE-BioRID	6	108	92	134
	EvaRID	12	109	77	177
High (HP)	FE-BioRID	9	259	138	165
	EvaRID	13	147	93	138

The seatback angle differed between models and crash pulse severity, showing that the angle was higher for the FE-BioRID than for the EvaRID (Figure 6). The deflection angles were similar for the LP and MP and the maximum seatback angle close to twice as high as those in the HP.

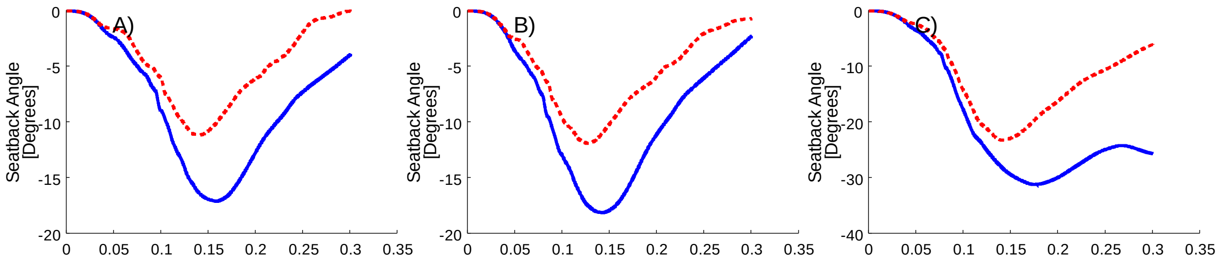

Figure 6. The seatback deflection angles for the LP (left) MP (middle) and HP (right) of the FE-BioRID (solid blue line) and the EvaRID (dotted red lines).

Discussion

Real-world car accident statistics shows that females have a higher risk of sustaining whiplash injuries than males. Alarmingly, studies have also shown that anti-whiplash concepts are more effective for males than females (Kullgren and Krafft 2010 and Kullgren et al. 2013). In order to improve whiplash protection concepts for both sexes, and in particular for females, it is important to better understand what influences the dynamic response and the injury risk. The average male and female differs in among others height, weight, joint stiffness and geometrical properties (Carlsson et al. 2014). These factor might influence the dynamic interaction with the seat during a crash and thus the injury protective performances of the seat. Mathematical simulations in this study with a model of an average male and an average female in one seat model concept showed that the results were consistent for all crash pulse severities with respect to differences in timing, and peak values between the FE-BioRID and the EvaRID. The Low and Medium pulse provided similar magnitude of angular displacement of the seat for both models, while the High pulse gave a larger response in both models. The relative angular displacement of the head to the T1 was consistently larger in the neck of the EvaRID model which was subjected to a larger extension than the neck of the FE-BioRID.

The simulations in this study was performed with one seat model concept. Further knowledge into what to aim for in the future in terms of seat designs providing the best protective performances for both males and females could be gained with simulations using both the average male and female models. The dimension of the torso of the average male and female differs in dimension such as weight, centre of gravity, width and height (Carlsson et al. 2014). The influence of how flat or curved the seat back from side to side is and the influence of specific components of the seat back and its influence on the protective performances on both parts of the population are aspects that could be quantified.

Mathematical simulations with average male and female dummy models showed differences related to both the crash severity and between the two dummy models in a given crash severity. For all three pulses the NIC values were higher for the EvaRID than for the FE-BioRID. In addition, a lower NIC threshold value has been suggested to be used for the female model (Schmitt et al. 2012). The NIC value occur early in the event, before the head to head restraint contact (Table 1 and Figures 2-5). This is in the retraction phase of the neck where hypothesises of injury causing loading has been formulated. A similar seat back deflection angle was found for the LP and MP (Figure 6) and the highest NIC values were calculated for the MP pulse. The LP and MP corresponds to the same change of velocity with a higher acceleration for the MP than the LP. Higher acceleration of the pulse has been shown to correspond to higher risk of injury (Krafft 1998). The results of the study highlight the need for an extended test matrix. The inclusion of an average female dummy model would provide seat developers with an additional tool to ensure improved whiplash protection also for female occupants.

The injury statistics shows that there is a need for assessing the protective performances of seats with models of both males and females in order to promote seat concepts that provide the best possible protection for the whole population. This study shows that using the mathematical models that are available today can provide insight that can be used in future testing.

Acknowledgement

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Driver behaviour and attitude is a key factor…

Sharyn Littler, Peter Styles, Robert Bryden and Judith Kuerschner

Abstract

Focusing on producing better drivers, competent and aware drivers, making better decisions and reducing risk on Australian roads.

Whilst we can be proud as a Nation that our road toll has reduced over the past decade, the number of serious accidents has not reduced, and this cannot be ignored.

Over 99% of crashes involve some degree of driver error. Driver decisions in the moments leading up to a crash, can in most cases prevent or reduce the severity.

An urgent focus needs to be placed on creating a "responsible" culture of drivers on our roads. A vehicle cannot be driven without a driver. Yet little credibility is placed on the value of focusing on improving driver education to improve road safety. It has been disappointing to see whenever this subject is raised in the road safety industry it is instantly dismissed by many.

It would appear this thinking has come about because of statements such as "even the most competent driver will still make mistakes", so the focus has been to remove the driver from the equation, in an effort to reduce the risk.

Whilst all drivers can make mistakes, what needs to be considered is that "aware drivers" have the ability to manage and correct those mistakes, and most importantly, can often anticipate the mistakes of other drivers.

The Safe System Approach as part of the National Road Safety Strategy is yet to realise its full potential when it comes to Safer People. It is far more effective to avoid crashes in the first place by adopting lower risk driving techniques.

In this regard, enthusiasts aim to be recognised as the leaders in safe driving practice and would welcome the opportunity to discuss this as part of the 2015 conference.

Introduction

The forward to the National Road Safety Strategy 2011-2020, acknowledges that whilst there has been a measurable decrease in deaths on Australian roads over the past decade, there has been slower national progress in reducing the number of serious injuries during the same time period.

Despite setting a target to reduce serious injury crashes by 30% by 2020, there continues to be little progress in the reduction of serious injuries, and this continuing trend can no longer be ignored.

It is the belief of the Motoring Advisory Council (MAC), that an urgent focus needs to be placed on creating a “responsible driving culture” in Australia; through a refocus on ‘Safer People’ as part of the National Road Safety Strategy, to ‘take action together’ by sharing the responsibility to use roads safely.

It is time for new thinking and a willingness to adjust priorities in order to see a measurable decrease in the number of serious injuries on the road.

Shift in thinking

Much focus has been placed on **"**surviving the crash**"**. With advancements in vehicle safety technology, infrastructure and trauma response, improvements are being made in these areas, and MAC fully support a continued focus in this area.

Unfortunately, little focus has been placed on **"**avoiding the crash**"** in the first place, as a measurable way to reduce the number of serious injuries on the road.

A holistic approach to the National Road Safety Strategy should include both;
The primary focus should be to reduce the number of incidents on the road and the secondary focus should be to increase the chance of surviving a crash, should one occur.

It needs to be remembered that the latest 5 Star ANCAP rating vehicle has the same road safety outcome as a 1965 Classic Vehicle, if it is not involved in a crash.

Driver decisions in the moments leading up to a crash can, in most cases, prevent or reduce the severity.

By implementing systems based on competence rather than compliance, better drivers/riders will be created, and will lead to a better road experience that is safer for all.

Safer People within a Safe System

Australia's National Road Safety Strategy (NRSS) is based on the 'Safe System' approach; ***Safer Roads, Safer Vehicles, Safer Speeds, Safer People***.

The MAC are calling for a stronger focus on 'Safer People' under the 'Safe System', with the aim to develop a responsible community of Road Users.

The unrealised potential of "Safer People", if realised, presents a real opportunity to produce a better road safety outcome for all road users.

Why Re-focus on Safer People?

- New advances in education and training pedagogy
- New educational research into how we learn, parental influence and cognitive neuroscience
- New technologies to support road user education and training
- Economical access to new technologies to support road user education and training. (Australian Naturalistic Driving Study).

Driver/Rider education and training, benefits not only the driver/rider but every other road user, including the more vulnerable road users.

Key themes

Low Risk Driving Practices

Using the road is never risk free, but it is a realistic goal to minimise that risk.

A workplace health and safety (WH&S) approach should be applied to minimising risk associated with using the road.

Competency, behaviour and attitude are key factors to reducing risk.

The 'human element' of road use can no longer be ignored. Competent, aware drivers/rider are lower risk road users, as they can anticipate and potentially avoid a serious incident on the road. (Underwood, Ngai, Underwood 2012)

Teaching situational awareness, knowing what is happening on the road around the road user, will enable road users to anticipate potential risk, thus minimising the risk to themselves and others on the road.

A focus on the WH&S Sector shows evidence that additional training for vehicle users has the result in less road incidents while in a work vehicle - therefore less cost to the employer, damage to person and property, lower insurance premiums, time off work due to injury, etc, as well as less lost time and productivity when an employee may be involved in a road incident in their own personal time as well.

The greater the community of road users practising low risk driving practices, the safer the road will be.

Education & Training

Education and training is an essential component for developing safer road users.

The validity of improving road user education and training cannot be ignored simply because prior research is not only now out dated, but has became a end unto its self.

Competent and aware road users have the ability to manage, and correct those mistakes, and most importantly, can often anticipate the mistakes of other road users. (Underwood, Ngai, Underwood 2012)

Educational research has shown that learning skills needed for an 'emergency' situation in a 'non-emergency' situation is more effective when those skills are required for an 'emergency' situation. (Westwell, Panizzon 2011)

'Whole of Life' Education

There are many opportunities to influence, educate and skill people for safer road use – from young children through to older drivers (whole of life learning).

Challenges

It is important to revisit the reasons why improving driver education to improve road safety crash outcomes has not yet been proven in Australia, and how this may have held back further research and advancement in this area.

"There is community support for driver education programs; however, the research evidence on the effectiveness of such programs in reducing serious crashes remains disappointing". (National Road Safety Strategy 2011-2020 – Safer People)

One obvious challenge when the focus is to avoid crashes, is in data collection, as a "crash avoided" is never recorded.

Summary

More emphasis needs to be placed on 'Safer People' under the 'Safe System' to reduce the number of serious crashes on our roads.

Look to the WH&S Sector for evidence of increased education and training translating to improved economic and social outcomes.

Education and training is a key component in producing safer road users. A move towards 'whole of life' education and skills development will develop people who can make safer on-road decisions.

A shift towards a 'responsible' road user culture in Australia is required; r*esponsible not just for self, but every other road user.*

A license is a privilege not a right.

Where to from here

This is merely the beginning of a new conversation around road safety, looking at one of the key Road Safety System elements which has not been in focus recently. Since the improvements to technology and road infrastructure have not led to the reduction in serious injuries on the road that was anticipated, an additional focus on the 'Safe People' element is timely.

While the Motoring Enthusiasts Community may not have all the answers to how best tackle the 'Safe People' element, as a group of responsible road users who are, often, under-represented in road incident statistics, and draw ranks from a wide cross-section of the community, this group have many suggestions as to how this element may be brought back into alignment with the others of the Road Safety System.

MAC is calling for an Industry lead summit around 'Road User Education and Training' to provide additional strategies, and work towards the cost and risk analysis of a range of strategies to bring Safe People to the fore of the community's focus.

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National Road Safety Strategy 2011-2020

Application of Program Logic for Policy Development and Evaluation

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Abstract

The Road Safety Policy Unit in Centre for Road Safety (CRS) is responsible for leading the development, review and implementation of policies and projects that lead to safer vehicles, roads, people and travel speeds in NSW, with policies that are evidence based with stakeholder and community input and involvement.

The program logic model has been adopted as a policy tool to provide an integrated policy view from a safe system perspective, and to provide a focus for policy development and evaluation. It is an analytical and conceptual tool that can be flexibly applied to different road safety issues and preferably at early stages of policy development. The schematic diagram demonstrates how policy input produces a result chain, showing how interventions or actions contribute to the desired changes at different levels of road safety outcome (short/ medium/ long).

In the past two years, the Policy Unit has actively applied the program logic model to help with the design of some key road safety initiatives in NSW including Safer Drivers Course, Mandatory Alcohol Interlock Program, and the national trial of Electronic Work Diaries. The Unit is now extending the application of the model to improve understanding and analysis of broad policy issues including distraction, speed, drug driving and pedestrian safety.

Use of the program logic model has had multiple benefits including facilitating strategic discussions for policy and program design, communications, performance monitoring and evaluation, and identifying gaps for improvement.

Introduction

The Centre for Road Safety (CRS) of Transport for NSW is responsible for developing and implementing road safety policies and programs to reduce the NSW road toll. The NSW Road Safety Strategy aims to reduce the annual number of fatalities and serious injuries by at least 30 per cent by 2020. The safe system approach is adopted to address a complex road transport system by developing integrated road safety measures that take into consideration risks to all road users, the road environment, the vehicle and travel speeds. This also means having effective supportive systems in place including the licensing system, enforcement of road transport laws, and targeted communication and education resources.

CRS works collaboratively with Roads and Maritime Services, NSW Police Force, NSW Department of Justice, key organisations that represent road user groups, other government and community groups to develop customer focused and evidence based road safety policies and programs.

To this end, CRS must demonstrate to the NSW Government and the community that the road safety investments in NSW have helped to reduce deaths and injuries, and contributed to a safe, reliable and productive transport network. This paper is written from a policy practitioner's point of view that outlines a strategic policy development and evaluation approach by using the program logic model. Its application has the potential to produce multiple benefits including engagement and communication with stakeholders, ongoing performance monitoring and evaluation of policy outcomes.

Overview of program logic

'Program logic' refers to the specific hypothesized causal links between the elements of a program and its intended results. Program logic can be visually presented in an 'outcomes hierarchy', which presents the outcomes a program is intended to produce at different times, and the assumed chain of cause and effect between the activities and the desired outcomes (see Frechtling, 2007 and Funnell and Rogers, 2011).

A generic hierarchy can be a useful starting point for identifying basic assumptions for a specific program of interest and developing an outcomes hierarchy for that particular program. Figure 1 presents an example of a generic outcomes hierarchy developed for motivational programs that use deterrence strategies – for more examples see Funnell and Rogers (2011).

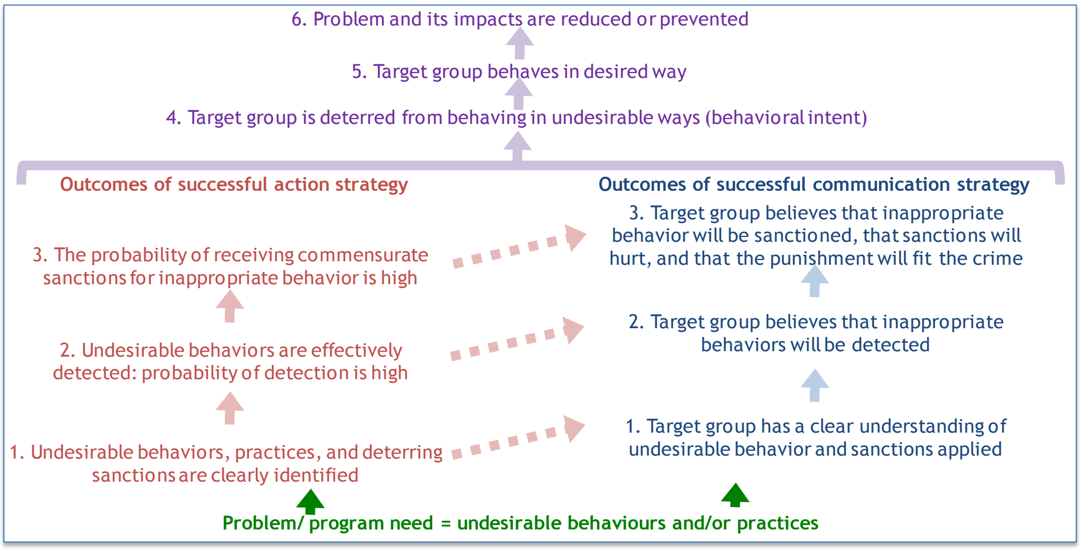

Figure 1: Example of a Generic Outcomes Hierarchy developed for motivational programs that use deterrence strategies

While the above example applies to a behavioural program within the road safety policy context, the model may capture any or all of the key components of the safe system approach – that addresses the road user, the road, the vehicle and travel speed, where appropriate.

Another way to view the program logic model is as a proposed framework for change and the required actions to bring about change (Funnell & Rogers, 2011). This involves undertaking a situation analysis to identify problems and opportunities and understand the causes and consequences of problems; to decide on the policy or program scope; and to articulate an outcomes chain that shows the assumed or hypothesized cause and effect between immediate and intermediate outcomes and ultimate outcomes or impacts. Program activities are then identified and developed to achieve each of the outcomes in the outcomes chain.

By drawing out the logic as a diagram, a clearer picture is formed regarding how the program is assumed to work. This approach has been applied to several road safety programs in NSW, and the following sections provide some recent examples.

Application of program logic model: Safer Drivers Course

The Safer Drivers Course was rolled out in NSW from July 2013 as a NSW Government commitment to address the over-representation of young drivers in the road toll, especially in the first six months of independent driving after attaining the provisional driver licence.

The course was designed by a board of independent road safety experts to encourage young learner drivers to understand their vulnerabilities as a novice driver and to develop low risk driving strategies. This is a new approach to training learner drivers combining theoretical and practical components, addressing both attitudinal and behavioural aspects of driving, and not focussing on driving skills and road rules. This is an optional course that supplements the NSW Graduated Licensing Scheme (GLS).

The policy team at the time wanted to articulate how this course fits into the overall GLS and how it will contribute to the road safety outcome. The team applied program theory to help develop their first program logic model to clarify the intended assumptions and outcomes behind the course. The model has assisted the team to communicate succinctly what the course is about and how it contributes to the high level road safety outcome.

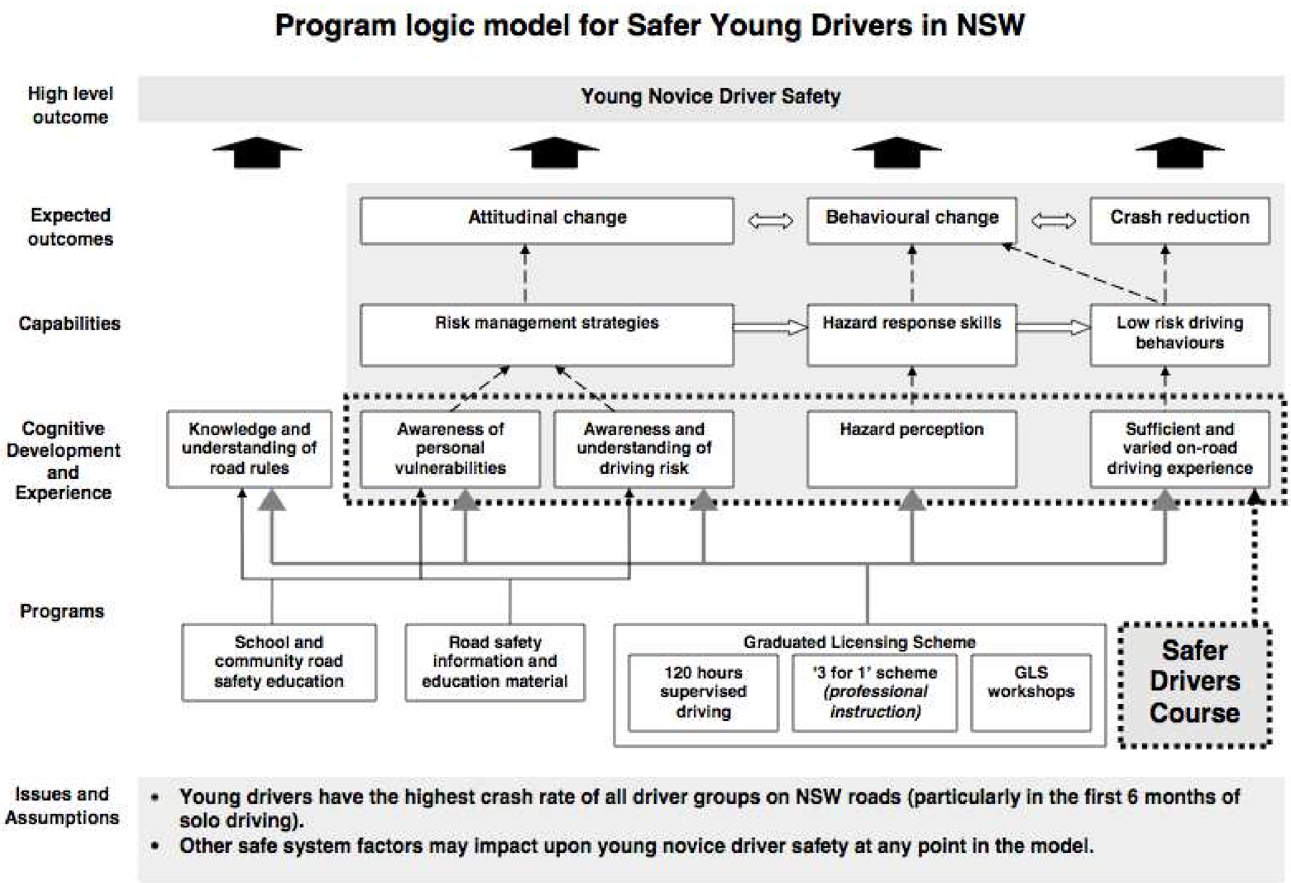

Figure 2: Program logic model for Safer Young Drivers in NSW

The key message that the model shows from the outcomes chain is that the course alone will not cause crash reduction for young drivers. However, the course alongside GLS, school and community education, and road safety information will contribute towards the desired attitudinal and behavioural change, and crash reduction.

Specifically the model highlights the key immediate outcomes of the course in supporting the young driver's cognitive development and experience, namely:

- awareness and understanding of personal vulnerabilities and driving risks
- improved hazard perception and its management
- have sufficient and varied on-road driving experience.

With further practice of the learnings from the course, it is hoped that the intermediate outcomes for young drivers will be acquiring capabilities in risk management strategies, hazard response skills, and low risk driving behaviours.

The model identifies the key development needs for the young driver to drive safely in a complex road environment, to have the appropriate attitudes and behaviour as a road user; and be supported by other safe system elements including education and information, and enforcement of road rules.

Program logic model for Mandatory Alcohol Interlock Program

There are approximately 26,000 drink drive offences in NSW each year. It is estimated that one in six offenders will re-offend with a subsequent drink driving offence within five years. Drivers convicted of drink driving offences pose a particularly high risk to the community. During the period 2007-2011, it is estimated that alcohol-related crashes cost NSW around $660M a year.

Most states in Australia already have a mandatory interlock program or are in the process of developing one. NSW Government replaced the voluntary program with a Mandatory Alcohol Interlock Program (MAIP) that commenced in February 2015. The new program is a major law reform in tackling drink driving in NSW and involved multiple government agencies including transport, police, justice, health, and the judiciary to agree to the policy settings and program elements. CRS wanted to be able to monitor the program and community impact and collect baseline and ongoing data to evaluate MAIP in the next five years.

MAIP is more complex than the former voluntary program with new program features that are essential to be monitored to determine if they contribute to effectively separating drinking from driving as intended. Research has shown that the interlock device is effective while it is installed in the vehicle, and offenders participating in the program will benefit from more long term behavioural change if their program is supported by alcohol rehabilitation and counselling.

With assistance from ARTD Consultants, a program logic model for MAIP was developed as shown in Figure 3.

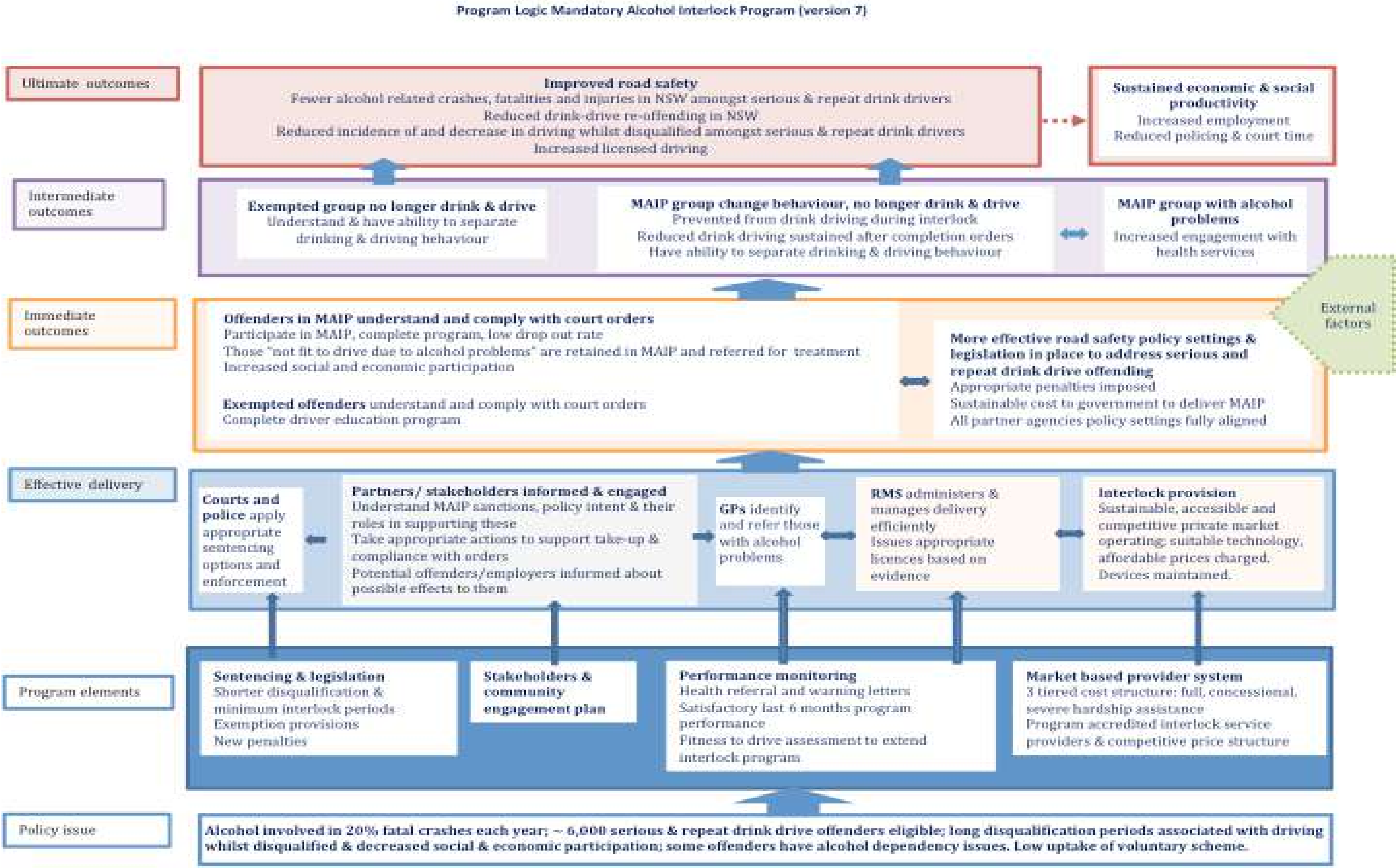

Figure 3: Program Logic Mandatory Alcohol Interlock Program

The road safety safe system approach is embedded in the development of the evidence based policy. Evidence was based on research on alcohol interlock programs world- wide, the process evaluation of the NSW voluntary program, crash and data analysis, and consultation with Australian jurisdictions and NSW government and community agencies. MAIP is a behavioural change program supported by an enforcement and penalty regime to provide the necessary deterrent effect to encourage offenders to remain and comply with program requirements.

The outcomes chain in the above program logic model for MAIP includes:

- having the right program elements to address the policy issue of drink driving
- having effective program delivery through the courts, interlock providers, treating doctors and licensing authority
- resulting in immediate outcomes of offenders complying with court orders to separate drinking and driving
- leading to intermediate outcomes of more lasting positive behavioural change from offenders to stop drink driving
- with the ultimate road safety outcomes and potential impact on more sustainable economic and social productivity.

The MAIP detailed program elements and delivery approaches form the integrated activities to be delivered by multi agencies and parties, to bring about the individual outcomes on the outcomes chain.

How can Program Logic shape an evaluation?

As outlined earlier, development of a program logic model enables the program to be described in terms of its intended outcomes. These outcomes can form a logical hierarchy, which can be used as a framework for evaluating the program.

Formulating a program logic can assist in the development of an evaluation plan for that program, whether it is a process, impact or outcome evaluation. This includes determining the evaluation approaches and data categories for the whole program and each of its initiatives (Cameron, 1999).

The broad data categories that can be measured for road safety evaluation include:

- Change in community awareness
- Change in road user risk perception and/or attitudes
- Change in road user behaviour
- Change in crash outcomes and/or crash risk
- Efficiency and effectiveness of program implementation

Based on the above approach, program logic models have been used to develop specific evaluation frameworks for several road safety programs in NSW, including the Safer Drivers Course and MAIP. For example, an evaluation framework has been formulated based on the MAIP program logic model with the following key questions:

▪ How has MAIP contributed to the NSW Road Safety Strategy 2012-2021 goal of achieving a safer community through reducing alcohol related road deaths?
▪ Overall, how well have the key partner agencies/ agents delivered the different program elements of MAIP and how can delivery be improved?

- Are the program design and settings meeting the policy objectives and what changes might be made to make program more effective?
- To what extent has MAIP addressed its target group of serious and repeat drink drivers?
- Are there any positive or negative indirect consequences as a result of implementing MAIP for participants, the government or the broader community?

Discussion

The program theory as in Funnell and Rogers (2011) has provided a useful framework for the development of road safety policy and programs. Application of program logic models have helped to facilitate a dialogue among key stakeholders to improve understanding and clarity of the road safety problem, and the development of the outcomes chain based on critical reasoning and road safety assumptions.

The development of a program logic model adopts a strategic planning approach and stakeholder engagement process to identify issues from all perspectives and to reach consensus on policy settings, strategic outcomes and actions. The model also provides a powerful communication tool to integrate the complex and multi-faceted policies and programs onto a single page.

Importantly, in clearly articulating a program’s intended outcomes and interdependencies, the program logic model allows for clear consideration of evaluation questions, approaches and data collection. It allows for an evaluation framework to be developed early in program implementation, as observed for the Safer Drivers Course and MAIP in NSW.

The model also provides an accountability framework for stakeholders to be responsible for implementation of their specific program elements. It provides a framework for the development of performance measures, for ongoing program monitoring, evaluation and improvement.

It is possible and desirable to integrate the development of the program logic model with road safety safe system approach to ensure that outcomes and actions include key evidence and components that contribute to a safe system.

While the program logic model is a valuable policy and program development tool, it is important to understand its application to optimise its use and undertake other complementary measures to overcome any limitations.

As the conceptual framework is constructed at a particular point in time, its validity over time needs to be reviewed and confirmed. Ongoing monitoring and evaluation may identify improvement required for policy and program refinements to ensure the meeting of the ultimate road safety goal. Emerging issues due to cultural and technological changes (uncontrolled external environmental influences) may require new actions and solutions.

The development of the program logic model relies on historic and existing evidence/ knowledge to construct the framework. However, the framework then provides a basis to monitor and improve on future policies and programs.

The CRS Policy Unit is now extending the application of the model to improve understanding and analysis of broad policy issues including distraction, speed, drug driving and pedestrian safety.

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Reduction of speed limit from 110 km/h to 100 km/h on certain roads in South Australia: a follow up evaluation

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Abstract

In July 2003, the speed limit on approximately 1,100 km of rural arterial roads in South Australia was reduced from 110 km/h to 100 km/h. An earlier study, conducted in 2006, found that this speed limit change was associated with a 19.7 per cent reduction in casualty crashes. However, this finding was not statistically significant, potentially due to the limited quantity of crash data available at the time. This paper details a follow up investigation using more crash data (10 years before and 10 years after the speed limit change). The number of casualty crashes on the subject roads since the speed limit was lowered was found to be 27.4 per cent lower than would have been expected if the subject roads had simply matched the reductions on the control roads (that remained at 110 km/h). This reduction was found to be statistically significant with 95% confidence limits of ±12.4%. While the methodological design of the study was not ideal, the size of the effect, the consistency of the various elements, and agreement with other research provides rather convincing evidence that the lowered speed limits were effective in reducing casualty crashes by a large amount.

Introduction

In July 2003, the speed limit on approximately 1,100 km of rural arterial roads (made up of 73 road sections) in South Australia was reduced from 110 km/h to 100 km/h. Long et al. (2006) investigated the change in casualty crashes on these road segments, as well as on 8,671 km of control road segments where the speed limit remained at 110 km/h, using data from two years before and two years after the speed limit reduction. This earlier investigation found that the speed limit change was associated with a 19.7 per cent reduction in casualty crashes but this result was not statistically significant, potentially due to the limited quantity of crash data available.

Other research from Australia on the effects of reducing the speed limit from 110 km/h to 100 km/h has shown similar results. In 1987 the speed limit on the Victorian freeway network was increased from 100 km/h to 110 km/h. Then in 1989 the 110 km/h speed limit was removed and a 100 km/h limit was reintroduced. Sliogeris (1992) investigated the effect that these speed limit changes had on the rate of casualty crashes. It was found that casualty crashes increased by 25 per cent following the speed limit increase and decreased by 19 per cent following the subsequent speed limit decrease.

An investigation into the effects of a speed limit reduction from 110 km/h to 100 km/h on the Great Western Highway in rural NSW was conducted by Bhatnagar et al. (2010). A reduction in mean travelling speeds, from above 102 km/h to less than 98 km/h, was accompanied by a reduction in casualty crashes of 27 per cent. The analysis did not make use of control sites.

International research has also produced evidence that a reduction in the speed limit on high speed roads will result in a corresponding reduction in crash frequency.

An investigation by De Pauw et al. (2014) into the effect of reducing speed limits from 90 km/h to 70 km/h on Flemish highways found a statistically significant decrease of 33 per cent in the number of crashes involving serious injuries or fatalities.

Similarly, Jaarsma et al. (2011), who looked at the effect of the reduction of the speed limit from 80 km/h to 60 km/h on minor rural roads in the Netherlands, found a statistically significant decrease of 24 per cent in casualty crashes. Although it should be noted that the speed limit change was also complemented by infrastructure upgrades such as edge marking, speed humps, and raised platforms at intersections.

In the United States there have been several instances of speed limits being increased on high speed rural roads. A major trigger of such action was the repeal of the national maximum speed limit in 1995, which allowed each state to set their own speed limits for rural Interstate routes. As a result of the repeal many states increased the rural Interstate speed limit from 65 mph (105 km/h) to 70 mph (113 km/h) or 75 mph (121 km/h).

Farmer et al. (1999) investigated how the frequency of fatalities was affected in 24 states where the speed limit on rural Interstates was increased. Fatalities on rural Interstates in seven states that did not change the speed limit were used as a control. An increase in fatalities of 15 per cent was found, rising to 17 per cent if changes in mileage were taken into account.

A similar situation in the state of Iowa, which increased the speed limit on most rural Interstates from 65 mph to 70 mph in 2005, was investigated by Souleyrette and Cook (2010). A statistically significant increase of 25 per cent in total crashes was found. Increases of 52 per cent in night time fatal crashes and 25 per cent in serious cross median crashes were also identified but were not statistically significant.

The analysis presented below details a follow up investigation of the effect of the speed limit reductions on the road segments identified previously in Long et al. (2006). Casualty crash data on the subject road segments from ten years before and ten years after the speed limit reduction were analysed. New control road segments, where the speed limit has remained at 110 km/h during the longer analysis period, were identified. Mackenzie et al. (2015) provides further details on the analysis presented below.

Method

The investigation presented here consists of a before and after analysis of casualty crashes on the road segments where the speed limit was reduced from 110 km/h to 100 km/h. The before period spans 10 years, from July 1993 to June 2003. The after period also spans 10 years, from July 2003 (during which the speed limit was reduced) to July 2013.

Because of the considerable length of the analysis period, control road segments (where the speed limit remained at 110 km/h) were used to account for background changes in casualty crash numbers.

Defining subject and control road segments

As in the previous analysis (Long et al., 2006), the South Australian Department of Planning, Transport and Infrastructure (DPTI) provided a list of 48 roads (consisting of 73 unique segments) where the speed limit was reduced from 110 km/h to 100 km/h in July 2003. Another list containing all 151 roads (made up of 328 road segments) where the speed limit remained at 110 km/h through the analysis period of July 1993 to June 2013 was also provided by DPTI. These two lists defined the subject road segments and control road segments analysed in this study.

All major South Australian roads have an associated road code. Each coded road also has an associated start and end point such that a specific location along the road can be identified via a ‘run distance’, which is the travel distance from a designated start point to the point of interest. Each of the subject and control road segments is defined by a start and end run distance along a particular road that is specified by the corresponding road code.

Characteristics of subject and control road segments

It should be noted that the application of speed limit reductions to the subject road segments was not random and the control road segments were not matched characteristically (e.g. by traffic volume or level of infrastructure) in any way to the subject road segments.

The geographic location of the subject road and control road segments can be seen in Figure 1. The majority of the subject road segments are located on the Yorke Peninsula or within a few hundred kilometres of Adelaide. Conversely, the control road segments are located relatively far away from Adelaide and comprise several major arterial rural highways. Given that the majority of South Australia's population is located in and around Adelaide, the subject road segments are likely to experience greater traffic flows compared to the control road segments. Similarly, because of their remote location, there are likely to be differences in the safety infrastructure of the control road segments compared to the subject road segments.

The potential effect that these study deficiencies may have upon the results are covered in the Discussion section below. While these potential effects cannot be ignored, it is unlikely that the differences in the characteristics of the subject and control road segments would be sufficient to explain the crash reductions reported in the Results section.

Locating crashes in South Australia

Details of all police reported crashes that occur in South Australia are reviewed by DPTI and entered into the Traffic Accident Reporting System (TARS) database. Within the TARS database, crashes are located using road codes and run distances in three ways. The first is used to locate crashes that occur at major intersections by noting the codes of the two intersecting roads. Crashes that occur between intersections (or intersections with minor roads that do not have an associated road code) can be located by providing a single road code and run distance. A crash can also be located at an unknown point between two intersections by providing three road codes; the first code indicates the road on which the crash occurred and the remaining two codes indicate the bounding intersections between which the crash is located.

Crashes are often also located with GPS coordinates. However, the facilities to match GPS coordinates to the specified road segments were not available.

Identifying crashes on subject and control road segments

Data on all casualty crashes that occurred between July 1993 and June 2013 were extracted from the TARS database. Each crash was then categorised as occurring on a subject road segment, a control road segment, both a subject road segment and a control road segment, or neither type of road segment (in which case they were removed from the analysis).

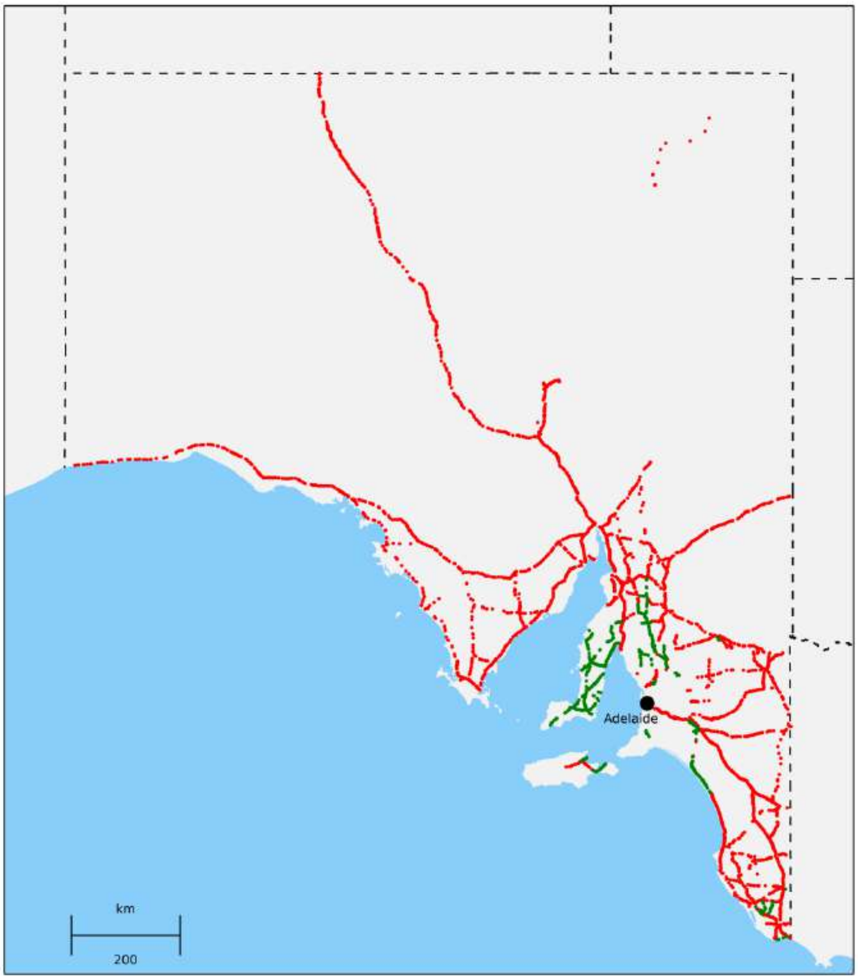
Crashes that were located with a single road and run distance were categorised relatively simply; checking for a match to a road on either the subject road or control road lists, and then investigating whether the run distance was situated between the start and end point of the corresponding segment.

For crashes located with two or three road codes, the categorisation process was more complex. First, those crashes that occurred on a subject or control road were identified. This was achieved by checking for a match to either of the intersecting roads for crashes located with two road codes, or to the main road for crashes located with three road codes. Next, a manual check was conducted to establish whether the intersecting road or both bounding roads were situated between the start and end point of the subject or control road segment.

Using these methods, there were 935 crashes identified on subject road segments and 4,884 crashes identified on control road segments. There were 105 crashes categorised as occurring on both a subject road segment and a control road segment. Since these crashes were unable to be definitively categorised they were removed from the analysis.

Figure 1 shows the location of all the identified crashes on both the subject and control road segments. These data points were mapped using the GPS coordinates associated with each crash.

Figure 1. Location of crashes on subject road segments (green dots) and on control road segments (red dots) between July 1993 and July 2013



Results

Because the speed limit on the subject road segments was reduced in July 2003, the data analysis is conducted using financial years (i.e. beginning July of one year and ending June of the following year).

The casualty crashes identified in each financial year on the subject road segments and the control road segments is shown in Table 1. The table presents the number of crashes split into the before and after periods and disaggregated by crash severity. The total number of casualty crashes (of all severities) on the subject road and control road segments per financial year is also shown in Figure 2.

The average number of crashes on both the subject road segments and the control road segments declined from the before period to the after period. This reduction in the average number of crashes was apparent for all severity categories apart from crashes that resulted in injuries that required hospital treatment on control road segments, which showed a slight increase from the before to the after period.

Table 1. Number of casualty crashes on the subject and control road segments per financial year (1993/94 - 2012/13) by crash severity

Period	**Financial year**	**Subject road segments (by crash severity)**					**Control road segments (by crash severity)**				
		Doctor	Treat	Admit	Fatal	Total	Doctor	Treat	Admit	Fatal	Total
Before (110 km/h on subject roads)	1993/94	5	23	23	4	55	18	96	112	27	253
	1994/95	6	23	23	3	55	21	123	88	14	246
	1995/96	4	27	36	4	71	18	105	123	36	282
	1996/97	8	19	19	3	49	18	104	115	20	257
	1997/98	3	23	18	3	47	14	99	102	19	234
	1998/99	7	26	19	4	56	12	111	107	23	253
	1999/00	4	32	17	3	56	14	113	119	15	261
	2000/01	4	23	13	7	47	14	105	107	13	239
	2001/02	4	29	23	6	62	18	116	86	19	239
	2002/03	4	26	27	8	65	14	121	131	29	295
	Total	49	251	218	45	563	161	1093	1090	215	2559
	Average	4.9	25.1	21.8	4.5	56.3	16.1	109.3	109.0	21.5	255.9
After (100 km/h on subject roads)	2003/04	3	24	16	8	51	18	111	110	17	256
	2004/05	1	20	14	1	36	12	119	96	24	251
	2005/06	4	17	16	4	41	8	90	98	23	219
	2006/07	1	26	16	1	44	7	124	93	4	228
	2007/08	5	16	12	3	36	9	118	86	13	226
	2008/09	5	30	13	0	48	13	94	110	16	233
	2009/10	2	25	8	2	37	14	124	89	25	252
	2010/11	3	15	8	1	27	10	124	86	18	238
	2011/12	2	9	12	2	25	5	112	75	13	205
	2012/13	0	11	13	3	27	16	124	60	17	217
	Total	26	193	128	25	372	112	1140	903	170	2325
	Average	2.6	19.3	12.8	2.5	37.2	11.2	114.0	90.3	17.0	232.5

Doctor – Treated by local doctor, Treat – Treated at hospital, Admit – Admitted to hospital

In Table 2, the ratio of casualty crashes on subject road segments to casualty crashes on control road segments in each financial year is shown. The results are again presented disaggregated by before/after period and by crash severity. The ratio of the total number of casualty crashes per financial year is shown in Figure 3.

This method of using the ratio was utilised because it is a simple and straightforward way of using the control road data and has the advantage of not needing to specify a model (e.g. constant rate of decline) for the dependence on financial year.

The ratio results reveal that the decline in the number of casualty crashes from the before period to the after period was greater on the subject road segments compared to the control road segments. This is evidenced by the reduction in the average ratio from 0.2197 in the before period to 0.1595 in the after period. That is, the number of crashes on the subject road segments in the after period was lower than would have been expected if the subject road segments had simply matched the control road segment reductions. This greater reduction on subject road segments was found for all crash severity categories. When looking at Figure 3, the step drop in the ratio of crash frequency from the before period to the after period can be seen clearly.

Figure 2. Number of casualty crashes on subject road and control road segments per financial year (1993/94 – 2012/13)

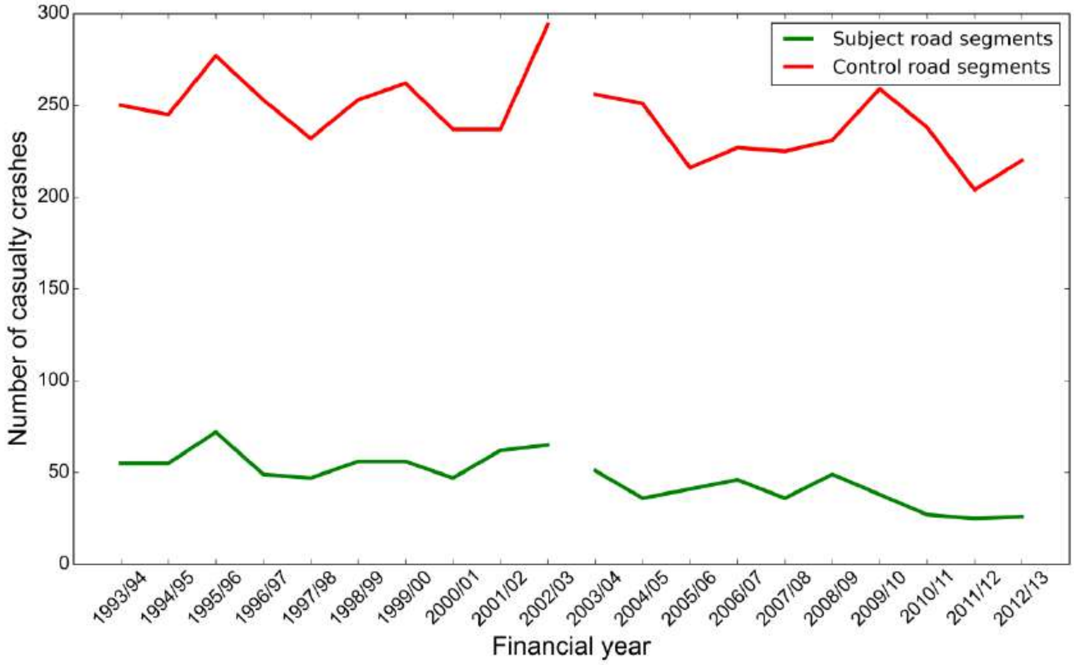
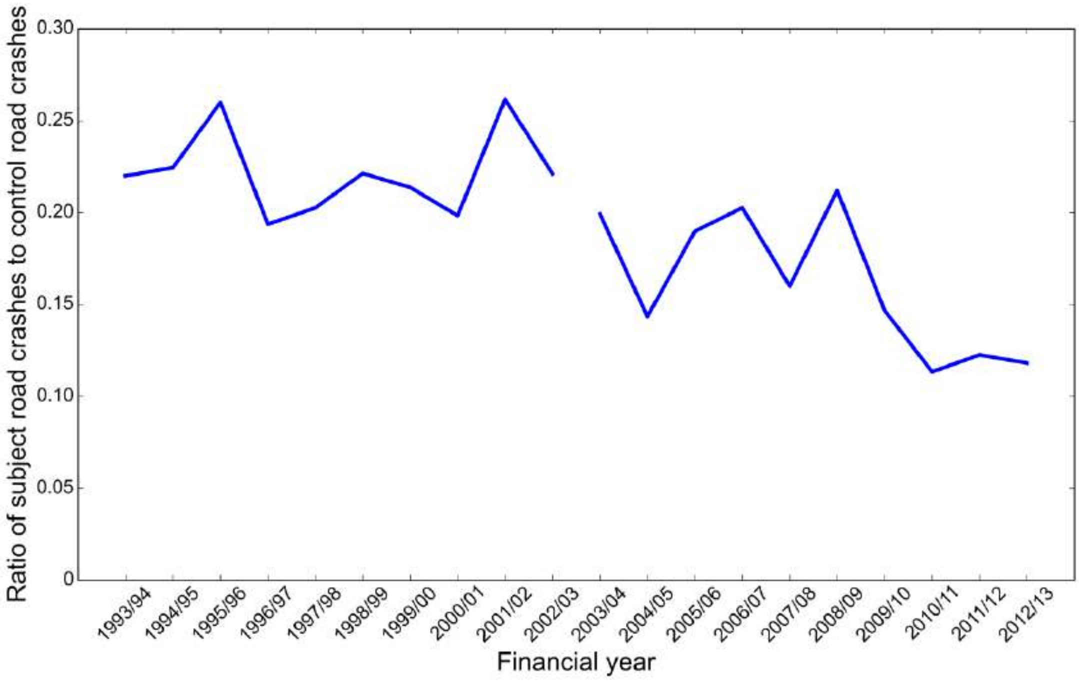


Table 2. Ratio of casualty crashes on subject road segments to casualty crashes on control road segments per financial year (1993/94 – 2012/13) by crash severity

Period	Financial year	Crash severity				Total
		Doctor	Treated	Admitted	Fatal	
Before (110 km/h on subject roads)	1993/94	0.2778	0.2396	0.2054	0.1481	0.2174
	1994/95	0.2857	0.1870	0.2614	0.2143	0.2236
	1995/96	0.2222	0.2571	0.2927	0.1111	0.2518
	1996/97	0.4444	0.1827	0.1652	0.1500	0.1907
	1997/98	0.2143	0.2323	0.1765	0.1579	0.2009
	1998/99	0.5833	0.2342	0.1776	0.1739	0.2213
	1999/00	0.2857	0.2832	0.1429	0.2000	0.2146
	2000/01	0.2857	0.2190	0.1215	0.5385	0.1967
	2001/02	0.2222	0.2500	0.2674	0.3158	0.2594
	2002/03	0.2857	0.2149	0.2061	0.2759	0.2203
	Average	0.3107	0.2300	0.2017	0.2285	0.2197
After (100 km/h on subject roads)	2003/04	0.1667	0.2162	0.1455	0.4706	0.1992
	2004/05	0.0833	0.1681	0.1458	0.0417	0.1434
	2005/06	0.5000	0.1889	0.1633	0.1739	0.1872
	2006/07	0.1429	0.2097	0.1720	0.2500	0.1930
	2007/08	0.5556	0.1356	0.1395	0.2308	0.1593
	2008/09	0.3846	0.3191	0.1182	0.0000	0.2060
	2009/10	0.1429	0.2016	0.0899	0.0800	0.1468
	2010/11	0.3000	0.1210	0.0930	0.0556	0.1134
	2011/12	0.4000	0.0804	0.1600	0.1538	0.1220
	2012/13	0.0000	0.0887	0.2167	0.1765	0.1244
	Average	0.2676	0.1729	0.1444	0.1633	0.1595

Figure 3. Ratio of casualty crashes on subject road segments to casualty crashes on control road segments per financial year (1993/94 – 2012/13)



The amount by which crashes were reduced on the subject road segments compared to the control road segments was investigated further. Table 3 shows the average before and after ratio for each severity category, along with the percentage ratio change which represents the additional crash reduction on the subject road segments beyond those found on the control road segments. An independent sample t-test was applied to the crash ratios in each financial year to determine the upper and lower 95% confidence limits of the change in crash ratio between the before and after periods.

The results from Table 3 reveal a 27.4 per cent reduction in all casualty crashes on subject road segments beyond that of the control road segments. The associated bounds of ± 12.4 per cent indicate that this reduction in crashes is highly statistically significant ($p < 0.0001$). The reductions in crashes that resulted in an admission to hospital or treatment at hospital were also statistically significant. However, the confidence intervals were too wide to determine whether there were greater reductions for crashes of a higher severity category.

Table 3. Change in the ratio of crashes between the before and after period by crash severity

Crash severity	Average ratio (before)	Average ratio (after)	% ratio change	Upper confidence limit	Lower confidence limit
Fatal	0.2285	0.1633	-28.56	25.24	-82.35
Admitted to hospital	0.2017	0.1444	-28.40*	-6.01	-50.78
Treated at hospital	0.2300	0.1729	-24.82*	-2.45	-47.19
Treated by doctor	0.3107	0.2676	-13.88	33.23	-60.99
Any severity	0.2197	0.1595	-27.40*	-39.82	-14.97

* Statistically significant

Looking again at Figure 3 it appears that there may be a general downward trend in the after period or a greater reduction in the ratio during the final three financial years. It is considered most likely that this effect is the result of random fluctuation but two other potential explanations are suggested.

The first is that there is a true downward trend in the ratio after the speed limit change in 2003. This could be due to drivers on the subject road segments taking some time to adapt to the new speed limit. If true, it would mean the 27 per cent reduction in crashes identified here is an underestimate of a long term effect and an overestimate of the short term effect.

An alternate explanation is that the reduction in the last three years is brought about by a continuation of a general downward trend in the ratio across both the before and after periods (with the possibility that the downward trend was increased in the after period). This could be the result of gradual changes in the distribution of traffic, infrastructure improvements, and/or enforcement on the subject and control road segments. If this was the case, then the identified 27 per cent reduction in crashes would be an overestimate of the mean effect.

Discussion

The number of crashes on the roads with speed limits lowered from 110 km/h to 100 km/h was found to be 27.4 per cent lower than would have been expected if these roads had simply matched the reductions identified on the control roads. The result was highly statistically significant, with the 95 per cent confidence interval being plus or minus 12.4 per cent.

The large size of this effect and relatively narrow confidence interval provides convincing evidence that the lower speed limits were highly effective in reducing casualty crashes. However, this study was not based on a randomised case control design where potential sites are randomly allocated into treatment or control groups to avoid selection and other biases. Therefore, there are other possible explanations for the results seen in this study. These need to be carefully considered when interpreting the results.

Regression to the mean on subject roads

The subject roads may have been selected, in part, because of their high crash rates. Part of this high crash rate could have been random variation in the high direction shortly before treatment that would not recur subsequently. This phenomenon is often referred to as regression to the mean and would lead to an apparent reduction that is not related to the treatment effect.

Such an effect is unlikely to be large given the relatively consistent crash numbers on the subject roads over the 10 years before the speed limit was lowered (see Table 1 and Figure 2). It appears that the treatment roads were chosen more on their characteristics than on their recent crash rate.

Comparability of control roads

In order to account for changes in other safety measures over the course of the study (such as safer vehicles and general road improvements) a control group of roads was used. This consisted of road segments that remained at 110 km/h over the study period. However, this group of roads is not directly comparable to the subject roads. The control roads included major highways and multilane roads throughout the State, whereas the subject roads were generally arterial two lane roads closer to Adelaide (see Figure 1). If there were significant differential effects on the two road types that coincided with the 2003 speed limit change on the subject roads, then an apparent effect could be produced that is not representative of the actual effect of the speed limit change. Such effects cannot be ruled out but the ones that could conceivably have lowered crashes on the subject roads or increased crashes on control roads (which would lead to the observed change) are considered below:

- A decrease in traffic on subject roads or an increase on control roads

- An upgrade of infrastructure on subject roads
- A change in the type of traffic on the subject or control roads - for example, a reduction in the number of motorcycles and bicycles on subject roads which would lead to fewer casualty crashes
- An increase in the level of enforcement on the subject roads compared to the control roads from the before period to the after period (or vice versa)
- A change in crash reporting (or processing) by the police responsible for the rural areas that encompass the subject or control road segments.

Each of these effects may produce gradual changes over time but it was considered unlikely that any could have occurred with sufficient rapidity or intensity so as to result in the sudden and significant reduction in injury crashes between the before and after period observed here. Thus, while the possibility remains that the results of this study are an artefact of the roads analysed rather that the reduction in speed limit, it seems unlikely.

Conclusion

While the present study is not definitive, the results together form a consistent picture:

- A distinct drop in casualty crashes is apparent on the subject road segments after the speed limit was lowered
- There is a long-term trend of a reduction in crashes on the control road segments that remained at 110 km/h
- Making allowance for this reduction by calculating the ratio of crashes on the subject road segments to crashes on control road segments, an extra reduction on the subject road segments is detected
- The subject road segments differed from the control road segments, but no likely confounding effects could be identified
- These results are consistent with other research on speed, speed limits and casualty crashes.

While the study has some methodological limitations, the size of the effect and the consistency of the various elements provide rather convincing evidence that the lowered speed limits were effective in reducing casualty crashes by a large amount.

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Establishing a testing capability for the assessment of Autonomous Emergency Braking (AEB) and Forward Collision Warning (FCW) in Australia

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Abstract

Advanced driver assistance systems (ADAS) such as autonomous emergency braking (AEB) and forward collision warning (FCW) systems are increasingly being developed and introduced into the Australian vehicle fleet. These active safety systems are designed to detect potential collisions and alert the driver and/or apply the brakes of the vehicle to minimize the severity of the collision or stop it from occurring at all. The potential for these technologies to reduce crash speeds or eliminate the crash altogether is substantial and they are predicted to result in a significant reduction in road trauma. However, not all AEB/FCW systems operate in the same way or provide the same level of benefit to the road user. Different systems utilise different types of sensors, operate at different speeds/ranges, and respond to critical situations in different ways. It is therefore important that AEB/FCW systems made available in Australia can be tested and rated for effectiveness. This paper summarises the development of an AEB/FCW evaluation capability by the Centre for Automotive Safety Research. Preliminary results obtained during the testing of an AEB system currently available in Australia are presented.

Introduction

In recent years a number of new vehicle technologies have been developed under the banner of advanced driver assistance systems (ADAS). These technologies make use of advanced sensors to assist with various components of the driving task. Some ADAS technologies are designed to identify when there is potential for a collision to occur and either warn the driver or take some kind of avoidance action automatically. Electronic stability control (ESC) is an example of an ADAS technology that has proven to be very successful. Other examples of ADAS technologies that are emerging or currently being developed include lane departure warning (LDW), lane keeping assist (LCA), blind spot detection (BSD), and vehicle to vehicle communication (V2V).

Some of the most promising of these emerging technologies, in terms of crash avoidance and impact severity mitigation, are autonomous emergency braking (AEB) and forward collision warning (FCW). Several research papers and expert opinions have agreed that AEB and FCW will contribute significantly to the reduction of road trauma into the future and have the potential to considerably reduce the human and financial costs of road crashes (Rosén, 2013; Kusano and Gabler, 2012; Doecke et al., 2012).

AEB and FCW systems both utilise forward facing sensors that are designed to identify objects in the vehicle's travelling path. The distance and speed of any objects that are detected by the system can then be used to determine whether a crash may be about to occur. When this 'crash potential' reaches a certain critical level the AEB and FCW systems respond in different ways. A FCW system will alert the driver to the potential emergency situation through auditory, visual, or haptic warnings which can increase in intensity if the driver takes no action. An AEB system will often incorporate driver warnings (in a similar manner to a FCW system) but will additionally apply the vehicle's brakes automatically if there is no driver response. Automatic braking is typically triggered at the last possible moment, with just enough time/space for the vehicle to avoid colliding with the object in front.

AEB and FCW systems are often divided into two categories depending on the driving conditions in which they are designed to operate. Some are designed to work at low speed (60 km/h and below) in stop-go, urban driving conditions. Other systems operate at higher speeds (between 60 and 100 km/h) and are targeted at highway type driving. Insurance companies have shown considerable interest in the evaluation of systems that are able to reduce low speed, rear end collisions because these types of crash comprise a large proportion of claims. However, the evaluation of systems designed to avoid, or mitigate, collisions at higher speeds or with vulnerable road users are more relevant to reducing fatal and serious injuries resulting from road trauma.

Evaluation of systems

There are several reasons why AEB and FCW systems require evaluation. Research indicates that there are major differences between various AEB/FCW systems such as the range of speeds at which they are operational, the types of sensors used, the amount of time taken to identify a hazardous object or situation, and whether they respond to vulnerable road users such as pedestrians or cyclists (ADAC, 2012; Hulshof et al., 2013). Additionally there are differences in the way that systems respond to an identified hazard. For example, some may present audible warnings to the driver up until the last moment and then brake strongly, while others may brake lightly when a danger is initially identified and then more strongly if there is no response from the driver.

Conducting evaluations of AEB and FCW systems in Australia is considered important. The Australian fleet composition and driving environment are different to those of other developed countries and thus manufacturers may be inclined to desensitise (or even remove altogether) AEB and FCW systems from their vehicles, rather than have their systems not work correctly. Some of the considerations for AEB and FCW within Australia are listed below:

- The Australian fleet comprises a high percentage of utility and work vehicles
- Delineation is not provided or is of low quality on many Australian rural roads
- A considerable number of Australian roads are unsealed and can produce dusty conditions in hotter months which may affect the performance of AEB/FCW systems
- Some areas of Australia experience extreme weather conditions
- Many Australian rural roads are unfenced, allowing wild and domestic animals to wander onto the roadway.

The evaluation of AEB and FCW systems in Australia would ensure that the most effective systems are fitted to vehicles entering Australia and support the development of systems that are suitable for Australian conditions and crash types. It would also provide evidence to encourage faster take up of AEB and FCW systems in Australia through consumer demand. Finally, a local Australian evaluation capability would provide further opportunities for research and development of other current and future ADAS technologies.

Any evaluation of AEB and FCW needs to account for the various ways in which these systems operate to prevent or reduce the speed of frontal collisions. An evaluation protocol developed by EuroNCAP (Schram et al., 2013) addressed this by considering a range of collision scenarios relevant to AEB/FCW and identifying those that were recorded as occurring most frequently in European crash databases. Using this method meant that the evaluation would focus on crash scenarios that make the greatest contribution to road trauma. Three test scenarios are included in the EuroNCAP protocol and each involves the test vehicle approaching another (target) vehicle from behind. The first test scenario simulates an approach towards a vehicle that is stationary. The second scenario simulates an approach towards a vehicle that is travelling slower than the subject vehicle. The third simulates a situation in which a vehicle ahead brakes suddenly.

Developing a testing capability

Major pieces of equipment that are required to conduct the EuroNCAP testing protocol, such as accelerator and brake pedal robots, were either procured or developed by the Centre for Automotive Safety Research (CASR). A mock evaluation test was performed in order to demonstrate that the equipment could be operated and utilised correctly.

A Subaru Forrester equipped with an EyeSight AEB system was borrowed from Subaru Australia and each of the three evaluation test scenarios were performed (CASR, 2014). A target vehicle (see Figure 1) was borrowed from Bosch Australia. Note that several types of target vehicle exist which endeavour to appear as a legitimate vehicle when detected by both vision and radar based AEB systems. The ability of such target vehicles to represent the diverse Australian fleet composition could be an additional opportunity of future research.

Figure 2 shows the results of a successful run through the third test scenario. Both the test vehicle and target vehicle were travelling at a speed of 50 km/h with the target vehicle leading by a distance of 12 metres. The test then began with the target vehicle braking at a constant deceleration of 2 m/s^2. A few seconds later the AEB system on the test vehicle can be seen braking heavily to avoid a collision with the target vehicle. The minimum distance between the test and target vehicles was approximately 1.5 metres.

The travelling speed, vehicle separation, and rate of deceleration are all parameters specified within the EuroNCAP protocol. Each of these parameters was met within tolerance (grey areas in Figure 2) and the test was determined to have been performed successfully.

Note that the results shown in Figure 2 should not be considered as an official assessment of the Subaru Eyesight system as the full protocol, including warm up of brakes and tyres, was not conducted. Rather, the results should be viewed as an example of the capability of CASR to successfully perform the EuroNCAP evaluation test protocols.

Further testing that focusses on the evaluation of AEB/FCW systems which respond to pedestrians and other vulnerable road users such as cyclists is also planned.

Figure 1. Evaluation testing being performed

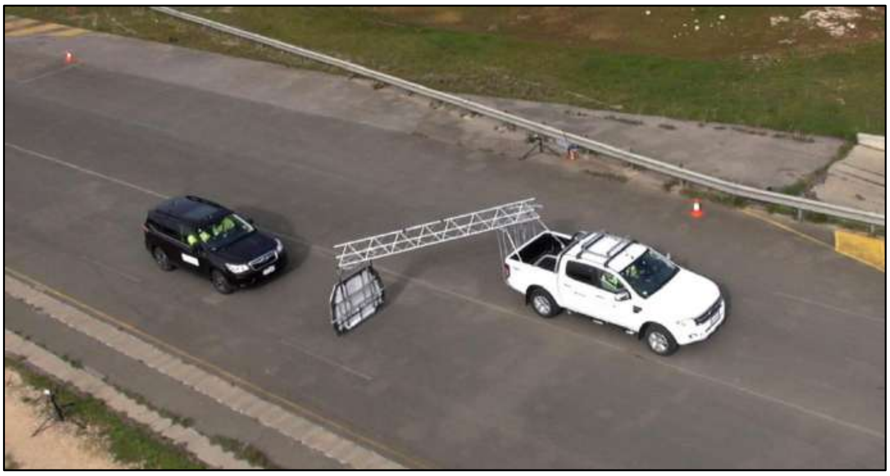
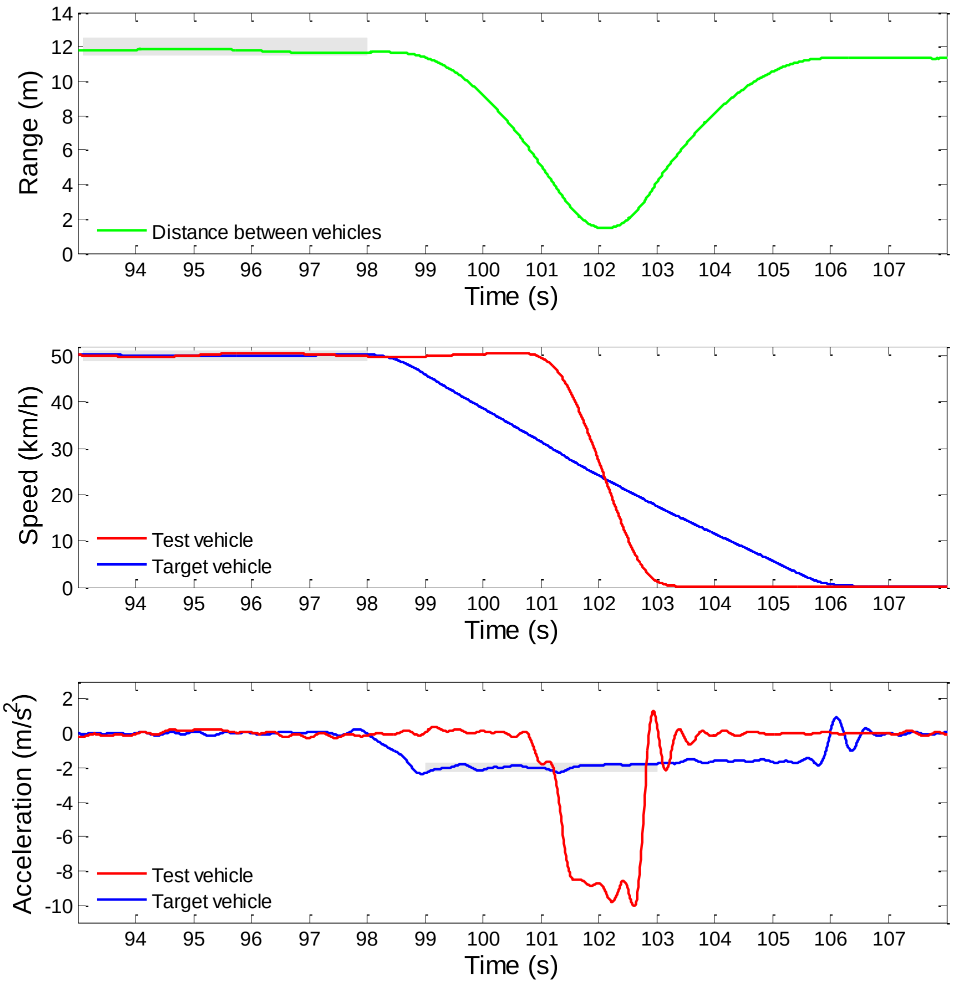


Figure 2. Performance of all equipment during an evaluation test



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An inexpensive technical solution for studying vehicle separations within real traffic flows using on-board sensors

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Abstract

Quantifying the separation between vehicles, both laterally and longitudinally, is an important step to understanding some crash events. Examples include, crashes that occur during the various phases of overtaking manoeuvres on high speed roads (pull out, pass, pull in) or where vehicles are passing bicycles on an adjacent travel path. The paper investigates a new option for measuring separation distance using inexpensive LASER distance measuring (LIDAR) devices. Six LIDAR devices were fitted to a vehicle and the accuracy of measurements to another vehicle during an overtaking manoeuvre were evaluated with off-the-shelf differential GPS technology. Data from the LIDAR devices was also used to calculate the passing speed and length of the overtaking vehicle, and the accuracy of these calculations was evaluated. Preliminary results show that the setup delivers results that are acceptable up to distances of 50 meters and at passing speeds up to 20 km/h. This inexpensive solution will facilitate research where separation distance in real traffic flow is an important consideration. Effective use of the technology should take into account possible weaknesses such as inaccurate device positioning and the potential for spurious data.

Introduction

Separation distance has been identified as a crucial factor in several types of crash. For example, Sun and Ioannou (1995) explored the relationship between longitudinal separation and the risk of a rear end collision. It was discovered that, along with other parameters such as reaction time and braking capability, the separation distance between the leading and lagging vehicles plays an important role in determining rear end collision severity.

Lateral separation is also a consideration in crash risk, especially for high speed rural roads. The width of lanes, centre medians, and roadside shoulders will affect the lateral separation between vehicles as well as to roadside objects like trees and poles. Garner and Deen (1972) discovered that as median width decreased, crash frequency increased. Similarly, an analysis of the effect of lane width and shoulder width by Gross and Jovanis (2007) found that, in general, crash rate increased as width decreased.

Another area where lateral separation distance has been a consideration is in vehicle-bicycle overtaking. If the lateral distance between a cyclist and a passing vehicle is too small a collision can occur. Research has shown that crashes resulting from a vehicle passing a cyclist too closely are more likely to result in severe injuries compared to other types of crash between cyclists and vehicle (Stone and Broughton, 2003). Even without a physical collision, the mere sensation of being passed by a vehicle too closely has been identified as one of the most uncomfortable experiences for a cyclist which can lead to instability and a fall (Guthrie et al., 2001; Parkin et al., 2007; Heesch et al., 2011). In light of this, Haworth & Schramm (2014) conducted a review of the literature on vehicle-bicycle passing distance studies and noted that further research is required to investigate what an appropriate minimum passing distance may be and whether drivers would be able to correctly judge this distance accurately.

Previous efforts to study separation distance in real traffic flows have made use of ultrasonic sensors (e.g. Walker et al., 2014) and video analysis (e.g. Parkin and Meyers, 2010). However, both of these technologies have limitations. Ultrasonic sensors are usually limited in range to just a few metres and have a cone shaped detection area which makes it difficult to locate objects precisely. Automatic video analysis can be useful but is also limited in range (accuracy per pixel degrades at distances greater than a few metres) and may require complex software to be developed (Ponte et al., 2014). The requirement for complex software can be overcome with human analysis but can be costly if large amounts of video require manual processing.

This paper investigates a new method of measuring separation distance with an inexpensive LIDAR device that claims accurate measurements (within 2.5 cm) up to a maximum of 40 metres. The potential for using the LIDAR device to measure separation distances and a validation of the accuracy during an experiment designed to emulate a real traffic environment is presented below.

Materials

LIDAR operates by emitting a laser beam towards a surface and analysing the light that is reflected back. The distance to the surface is calculated by precisely measuring the time between when the laser beam is emitted and returned. Some LIDAR units utilise rotating mirrors to scan the laser beam back and forth to build up a two dimensional matrix of distance data.

Because of the precise timing electronics, rotating mirrors, and optics, LIDAR units are usually expensive and applied to specific tasks such as 3D surveying or accurate machine control. However, an inexpensive module, aimed at hobbyists, has recently come to market (Pulsed Light 3D, 2015). This module, called the LIDAR Lite, is shown in Figure 1.

A microcontroller is used to request a distance reading from the LIDAR Lite module. The module then attempts to determine the distance to an object in its beam path. If successful, the distance is returned to the microcontroller. If the reading fails, for whatever reason, then a zero is returned to indicate an unsuccessful reading.

Note that the LIDAR Lite module is classified as a class 1 LASER and is not harmful if accidently directed into a person’s eyes.

Method

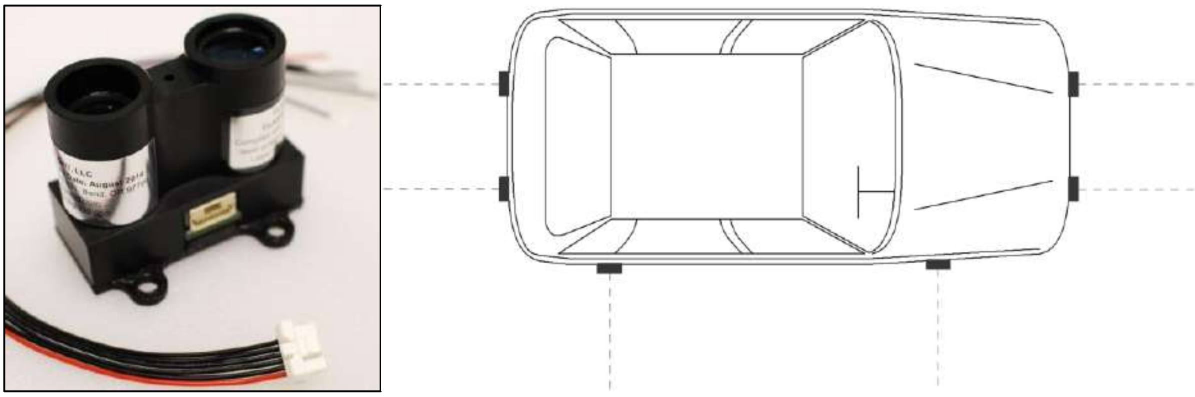
A Subaru Impreza was fitted with six LIDAR Lite modules. Two were mounted facing towards the front, two facing the rear, and two facing the right side as shown in Figure 1. The LIDAR modules were positioned and directed such that they would detect a typical vehicle travelling within their targeted zones. The rear LIDAR modules were mounted either side of the licence plate so that they would likely detect the front bumper (or bonnet leading edge) of a vehicle travelling behind. The side LIDAR modules were mounted to the right side wheel wells and directed slightly upwards so that they would detect the side of any vehicle that passed within a few metres. The front LIDAR modules were mounted similarly to the rear modules on either side of the licence plate where they would likely detect the rear bumper (or boot) of a vehicle travelling ahead.

The six LIDAR modules were connected to a microcontroller which was programmed to cycle as fast as possible through each module and request a distance reading. To improve the resolution of the overtaking speed estimate (see below), distances were requested from the side LIDAR modules twice per cycle. This resulted in eight readings during each cycle.

The total cycle time varied as the speed with which each LIDAR returned a reading (or determined that no reading was possible) differed depending on the circumstances at the time. However, a time of less than 273 ms was observed for 90 per cent of the cycles during the testing described below. For the side LIDAR modules this equates to a typical cycle time of less than 137 ms.

A faster cycle time can be achieved by using less LIDAR modules. The cycle time can also be reduced by increasing the communication rate between the microcontroller and LIDAR modules. However, this must be performed carefully as it can result in communication errors and invalid data.

Figure 1. LIDAR Lite module and mounting locations during testing



An overtaking test manoeuvre was used to investigate the data collected by the LIDAR modules. The subject vehicle, fitted with the LIDAR modules, was driven at a constant speed of approximately 60 km/h along a relatively straight section of road. Another vehicle (a Subaru Outback, referred to hereafter as the passing vehicle) then approached the subject vehicle from behind, pulled out, passed at a speed of around 70 - 80 km/h, pulled back in, and continued on for a few more seconds at which point the test was halted. This overtaking manoeuvre was repeated 18 times while the data from each LIDAR module was being recorded. No other vehicles were present on the road at any point during the tests.

To validate the data from the LIDAR modules, and evaluate their accuracy, a Racelogic Vbox dual antenna GPS system (Racelogic, 2015) was installed in both the subject vehicle and passing vehicle. The two Vbox systems are able to communicate in real time to continuously monitor and log the position of the passing vehicle relative to the subject vehicle with a claimed accuracy of better than 2 cm.

The microcontroller connected to the LIDAR modules was also connected to the subject vehicle Vbox system. All of the returned distance readings were transmitted to the Vbox such that they would be logged concurrently with the Vbox GPS positional data and facilitate a side by side comparison.

The data obtained from the front and rear mounted LIDAR modules were filtered to remove readings that were obviously spurious. Any group of sequential distance readings that were not sustained over a period of 0.8 seconds (before an invalid zero reading was returned) were deemed to be spurious and set to zero.

While each individual LIDAR module can detect distance, they can also be used in pairs to determine other relevant factors. For example, if the speed of the subject vehicle is also known (e.g. via a GPS system), then the time difference between detections from the pair of side LIDAR modules can be used to calculate the average overtaking speed. Furthermore, the duration of detection by the side mounted LIDAR modules can used to calculate the length of the overtaking vehicle.

The speed of the overtaking vehicle (s_o) can be calculated as shown in Equation 1, where s_s is the speed of the subject vehicle, d is the longitudinal distance between the front and rear LIDAR modules, t_f is the event time at the front LIDAR module, and t_r is the event time at the rear LIDAR module. An event can be noted as either the vehicle entering (rising edge) or the vehicle leaving (falling edge) the LIDAR module detection zone. The average of the two speeds calculated using the rising edge and falling edge was considered the most appropriate value to report.

Equation 1. Speed of overtaking vehicle

$$s_o = s_s + \frac{d}{t_f - t_r}$$

The length of passing vehicle (l_p) can be calculated as shown in Equation 2, where s_o is the speed of the passing (calculated above), $t_{1\to0}$ is the rising edge time of a LIDAR module detection event, and $t_{0\to1}$ is the falling edge time of a LIDAR module detection event. A calculation can be made using data from either the front or rear LIDAR module. The average of the lengths calculated using both the front and rear module, along with the average passing speed, was considered the most appropriate value to report.

Equation 2. Length of overtaking vehicle

$$l_p = s_o \times (t_{1\to0} - t_{0\to1})$$

The accuracy of these calculations will be affected by the cycle time of the LIDAR/microcontroller system. A faster cycle time will increase the accuracy and a slower cycle time will decrease the accuracy. The accuracy of Equation 2 is particularly affected by the cycle time as it relies on a previous calculation from Equation 1.

The Results section below will present a comparison of the data obtained from the LIDAR modules to the data collected by the Vbox systems.

Results

An example of the data collected by the LIDAR modules during one overtaking manoeuvre is shown in Figure 2. The figure is split into two with data from the LIDAR modules located in a longitudinal (front/rear) direction in the upper graph and data from the lateral (side) direction in the lower graph. Note that the rear left LIDAR module was discovered to be misaligned and thus did not capture any data during this test run. Also shown in Figure 2 is the corresponding longitudinal and lateral data recorded by the Vbox system. The Vbox lateral data is defined as the distance between the longitudinal centrelines of each vehicle. A second line that has been adjusted to compensate for the width of each vehicle, so as to display the distance between the side of one vehicle to the side of the other, is also shown.

Over the course of the test run the following points of interest can be observed:

- Point A - The passing vehicle approaches the rear of the subject vehicle and is detected by the right rear LIDAR module from a distance of approximately 45 metres to 20 metres.
- Point B - The passing vehicle is un-detected as it moves to the right and begins the overtaking manoeuvre.
- Point C - As the passing vehicle comes alongside the subject vehicle it is detected by the side mounted LIDAR modules; firstly the side rear and then the side front. The distance data varies by up to two metres (possibly due to reflections between the vehicles) but for

use with Equation 1 and Equation 2 only the passing vehicle's detection time and un-detection time is crucial.

- Point D - The passing vehicle un-detected again as it travels past the subject vehicle.

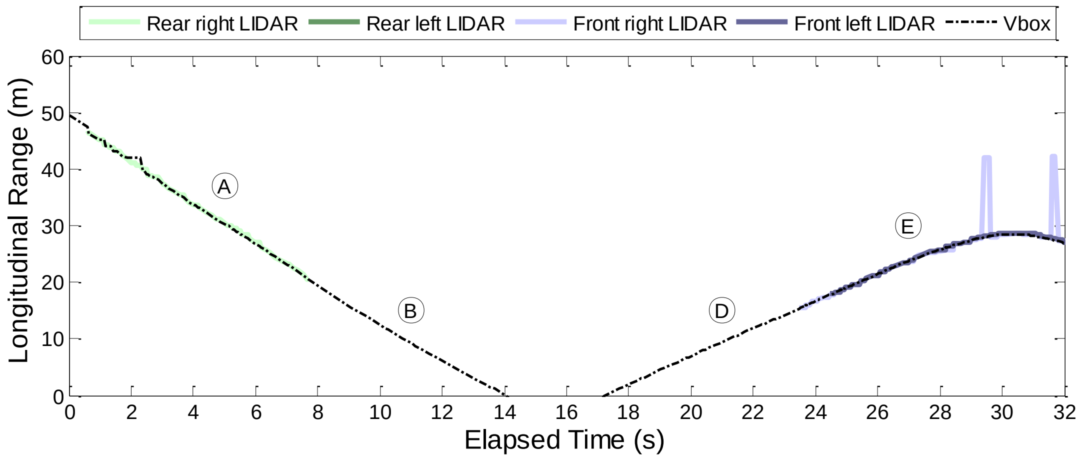
- Point E - The front mounted LIDAR modules detect the passing vehicle as it begins to move back into the correct lane, in front of the subject vehicle. As the passing vehicle returns to the correct lane it is detected first by the front right LIDAR module (at a distance of approximately 15 metres) and then the front left LIDAR module (at a distance of approximately 18 metres). The front LIDAR modules continue to track the longitudinal range of the passing vehicle up to a maximum distance of approximately 30 metres, at which point the test is halted.

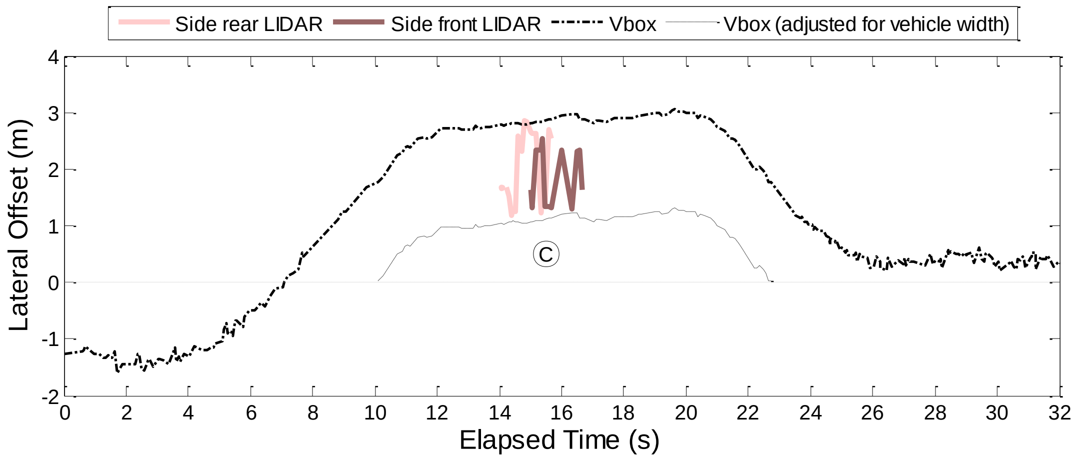
Some spurious readings from the front right LIDAR module, which were not removed by the cleansing process described earlier, can be observed towards the end of the overtaking manoeuvre. The frequency of such readings is explored below.

The data from the side mounted LIDAR modules has been restricted to distances of less than six metres to eliminate irrelevant readings picked up from distant roadside objects.

The subsections below utilise the aggregated data from all 18 runs through the overtaking manoeuvre to explore various aspects of the LIDAR module's suitability as an on-board separation distance measurement device.

Figure 2. Data obtained from LIDAR modules during a single run of the overtaking manoeuvre (see text for points of interest)





Lateral distance

The side mounted LIDAR modules were positioned low down on the subject vehicle and angled slightly upwards. This upwards angle was to ensure that some point of the passing vehicle would be detected by the LIDAR modules during overtaking. If the LIDAR modules were horizontally aligned, they may only have detected the wheels of passing vehicles or nothing at all. Because of the angled alignment the side LIDAR modules were not able to measure lateral distance and no comparison to the Vbox data was made.

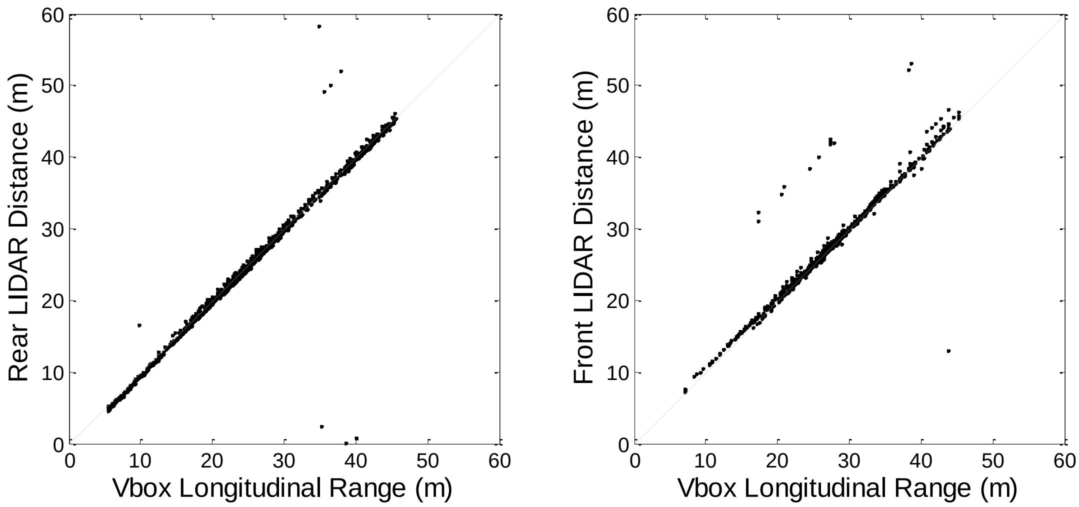
Longitudinal distance

The Vbox data was used to determine when the passing vehicle was directly behind or ahead of the subject vehicle and within a distance that it should be detectable by either the rear or front mounted LIDAR modules. More specifically, when there was a lateral offset of less than ± 1 metre and a longitudinal range of less than 50 metres between the passing and subject vehicles. If the passing vehicle was behind it was defined as being in the rear detection zone, and similarly for the front detection zone when the passing vehicle was ahead.

There were 1,524 readings requested while the passing vehicle was within the rear detection zone. The rear LIDAR modules returned a non-zero (i.e. valid) result for 53.8 per cent of these requests. The front LIDAR modules returned a non-zero result for 93.4 per cent of the 992 readings requested while the passing vehicle was within the front detection zone. The higher error rate for the rear mounted LIDAR modules was likely caused by the greater number of readings that were requested at long range, where small misalignments are made worse. A significant misalignment of the rear left LIDAR module was also discovered during testing. Further investigation found that the rear left LIDAR module returned a zero for 63.9 per cent of requested readings, compared to 28.5 per cent for the rear right LIDAR module.

Figure 3 compares the non-zero readings for the rear and front mounted LIDAR modules to the Vbox longitudinal range while the passing vehicle was within the rear and front detection zones. Analysis of the data found that the mean error between the rear LIDAR readings and the Vbox longitudinal range was -0.4 metres, with a 90th percentile spread of 1.3 metres. For the front LIDAR modules the mean error was also -0.4 metres, with a 90th percentile spread of 1.2 metres.

Figure 3. Non-zero LIDAR readings while passing vehicle in the rear and front detection zones, compared with Vbox longitudinal range



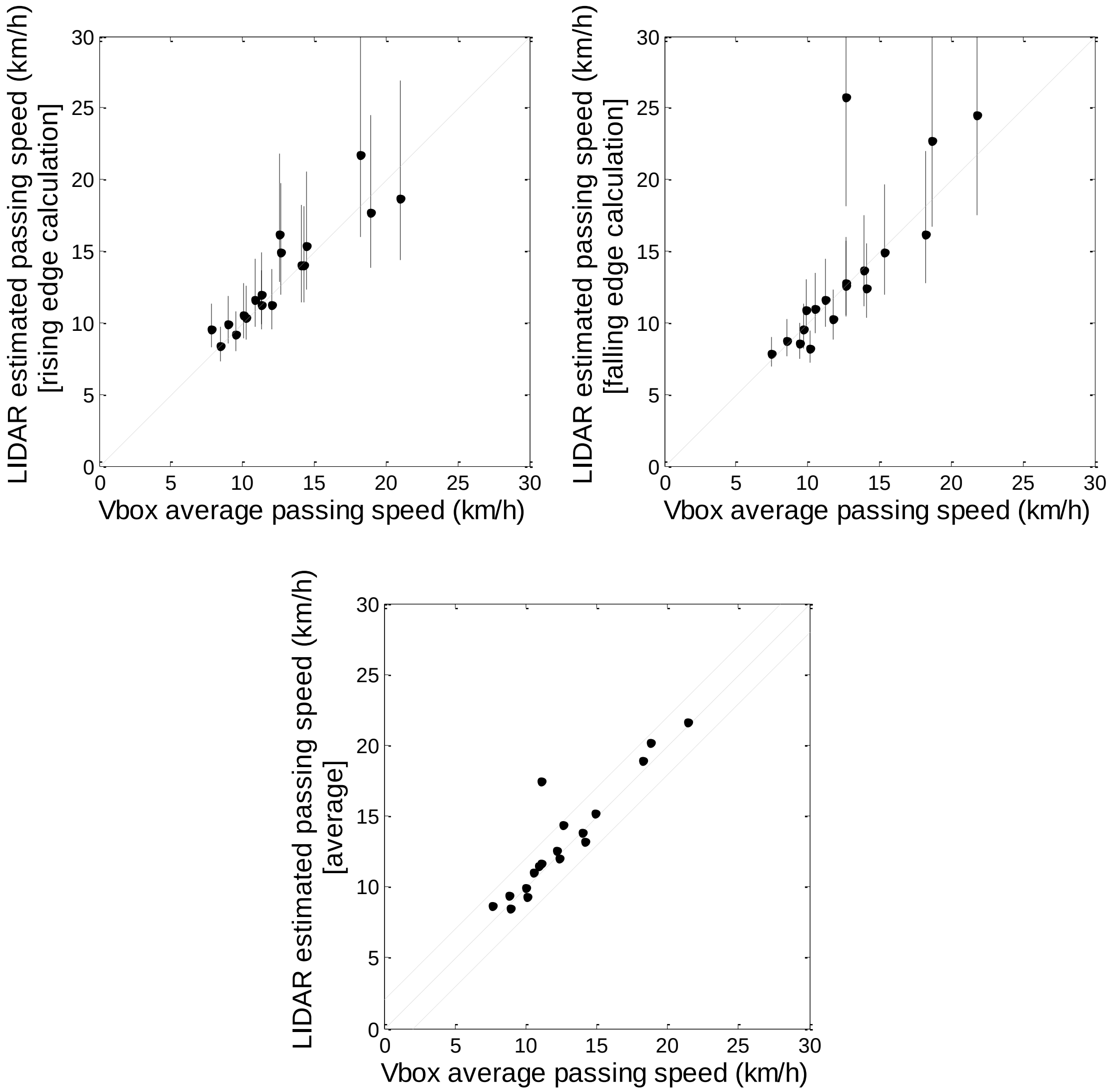
Passing vehicle speed

Using Equation 1, the speed of the passing vehicle as it travelled past the subject vehicle was calculated for each of the 18 overtaking manoeuvre runs. Passing speed was calculated using both rising edge detection and falling edge detection. Figure 4 shows the calculated speeds compared to the Vbox average passing speed. The cycle time during each measurement was used to determine upper and lower limits for each calculation which are shown as error bars.

It can be observed that the potential for error increases as passing speed increases. Greater accuracy may be achieved by reducing the cycle time in applications where determining passing speed is deemed to be important.

In the lower half of Figure 4 the average of the rising and falling edge calculations is shown plotted against the Vbox average passing speed. Lines showing an error of ± 2 km/h have also been plotted, showing that all but one of the averaged calculations lay within this zone.

Figure 4. Calculated passing speed based on rising edge, falling edge, and averaged, compared with Vbox average passing speed

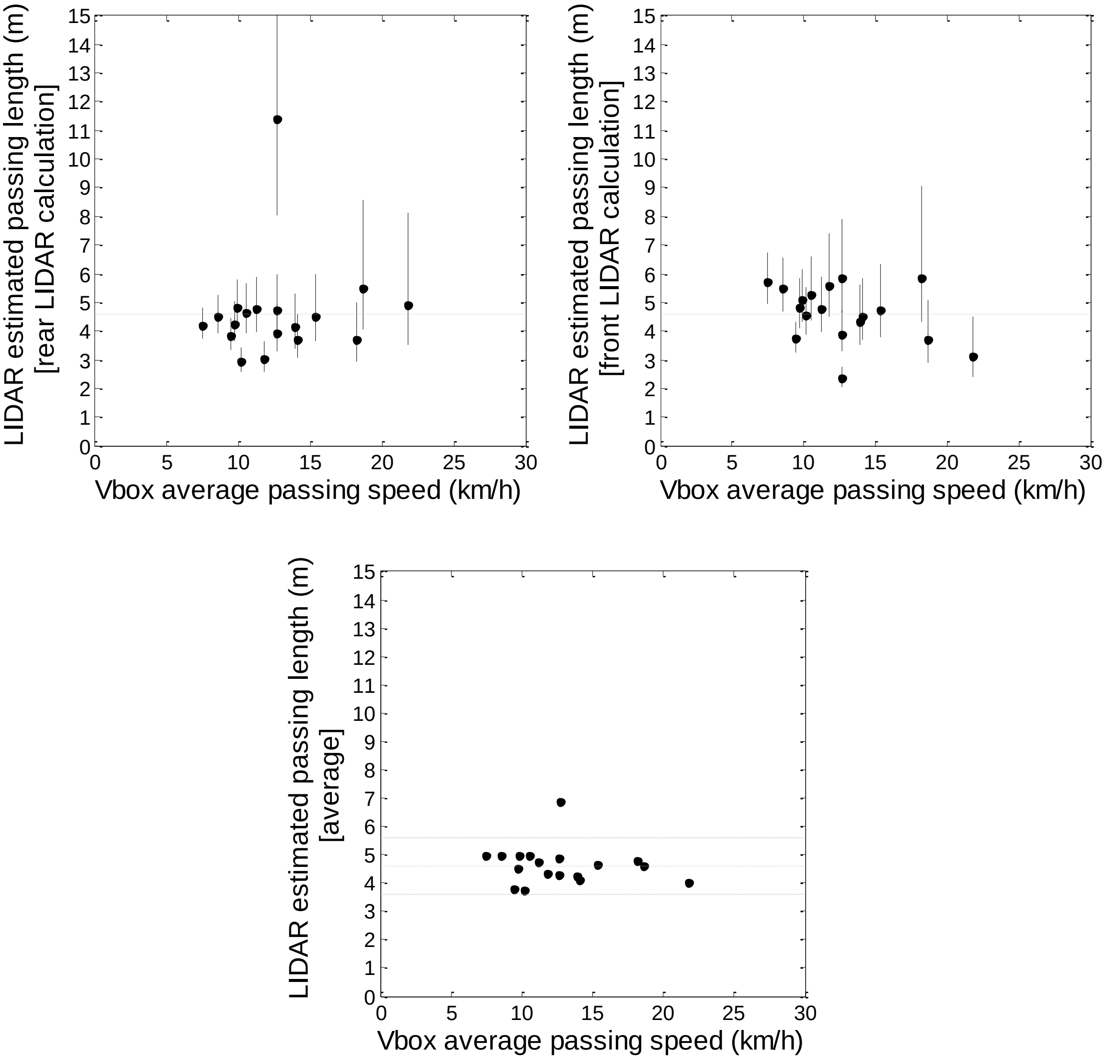


Passing vehicle length

Equation 2 was used to calculate the length of the passing vehicle based on the data from the side mounted LIDAR modules during the 18 overtaking manoeuvres. A separate calculation was made using both the rear LIDAR module and the front LIDAR module. The results of these calculations are shown in Figure 5 and compared to the manufacturer specified passing vehicle length of 4595 mm. The cycle time during each measurement was used to determine upper and lower limits for each calculation which are shown as error bars.

In the lower half of Figure 5 the average of the rear and front LIDAR module calculations is shown compared against the manufacturer specified vehicle length. Lines showing an error of ± 1 m have also been plotted, showing that all but one of the averaged calculations lay within this zone.

Figure 5. Calculated passing vehicle length based on rear LIDAR data, front LIDAR data, and averaged, with a comparison to manufacturer specific vehicle length



Discussion

This study has demonstrated an inexpensive method for measuring separation distances between vehicles in real traffic flows using on-board LIDAR modules. In the configuration that has been shown, the LIDAR modules were able to achieve successful readings from a vehicle located behind, to the side, and ahead during an overtaking manoeuvre. Methods for using the pair of side mounted LIDAR modules to calculate the speed and length of a passing vehicle were also demonstrated.

A Vbox dual antenna GPS system was used to validate the data readings from the LIDAR modules. A considerable proportion of the readings requested of the rear LIDAR modules were invalid compared to the front LIDAR modules but this was attributed to a greater number of requests at long range and the misalignment of the rear left module. The mean error between the valid front/rear LIDAR readings and the Vbox longitudinal range was found to be -0.4 meters. Calculation of the 90th percentile spread showed that the majority of LIDAR readings were within ± 0.65 metres of this mean.

Some of the error to the Vbox data is likely to have been caused by the shifting alignment of each LIDAR laser beam during driving. For example, the LIDAR may point at the front bumper of the vehicle behind while travelling on a flat road but if the following vehicle travels over a dip the bumper will lower and the LIDAR will strike further up the bonnet and return a longer reading.

Despite these errors, the accuracy of the LIDAR module is comparable to that of ultrasonic and video sensors used in past studies of separation distance. Additionally, the LIDAR module has a maximum range (50 meters) that is considerably further than ultrasonic or video and returns data that requires relatively little processing to utilise.

Calculations using data from the side mounted LIDAR modules predicted passing speeds that were within ± 2 km/h of the Vbox recorded average passing speed for all but one of the 18 overtaking manoeuvre test runs. While it is acknowledged that a sample size of 18 is small (and thus may not enable a complete understanding), this level of accuracy is encouraging and would be considered acceptable for many potential applications. If an application required greater accuracy then the cycle time could be decreased.

Further calculations using data from the side mounted LIDAR modules predicted the length of the passing vehicle. In all but one of the test runs, the predicted length was within ± 1 metre of the manufacturer specified length. While again acknowledging the small sample size, it is suggested that this accuracy would be sufficient to enable class of passing vehicle to be differentiated (e.g. motorcycle, car, or truck).

The findings presented here highlight the potential for the use of inexpensive LIDAR modules during studies of vehicle separation distance. The accurate measurement of longitudinal range, passing speed, and length of passing object have all been demonstrated.

However, some limitations and areas of caution were also identified during the testing process. Spurious readings were a fairly common occurrence and a filtering process was implemented in order to remove them. Despite this, some spurious readings remained (e.g. point E in Figure 2) and further, or more advanced, filtering may be required.

Highly reflective and oblique surfaces were observed to increase the chances of inaccurate readings. This was presumably the result of the LIDAR laser beam bouncing off several surfaces and returning an artificially long distance measurement.

Pointing the LIDAR module directly towards an intense light source, such as a vehicle headlight, was observed to increase the chances of a zero reading. This is unlikely to cause a problem during studies in real traffic flows as the dynamic nature of driving means the LIDAR will rarely be pointed directly into the headlights of a vehicle (and then only for a short time), but may pose an issue in other applications.

Finally, the misalignment of the LIDAR modules during installation (as was experienced in this study) can result in missed or inaccurate readings, especially at longer distances. The dynamic misalignment of LIDAR modules when travelling around bends or over uneven surfaces can also result in errors. This effect is unlikely to be overcome completely so restricting data collection to periods of straight line driving on flat roads is recommended. Utilising multiple LIDAR modules to monitor different sectors and act as a redundancy may also improve performance.

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Review of injury mitigation strategies and methods of assessment for passenger vehicle rollover crashes in Australia

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Abstract

Rollover crashes are one of the most severe crash modes for passenger vehicle occupants in Australia. They produce a wide range of injury patterns due to their ballistic and chaotic nature. Thus, multiple injury mitigation strategies are required to protect occupants against the large variety of potential loading and impact scenarios. Many strategies (e.g. side curtain airbags and upper interior head protection) have been employed to reduce the occurrence of injuries in rollover crashes with varying success. Recent epidemiological research regarding serious and fatal head, spine, and thoracic injury in pure rollover crashes has identified distinct injury patterns and characteristics. Further, the relationships between these injury patterns and specific occupant, vehicle, and crash factors have also been identified. This work reviews current and proposed injury mitigation techniques specific to pure rollover crashes in light of these recent findings and attempts to identify the types of injuries that each strategy would be most effective at reducing. The injury characteristics previously identified serve as a basis from which to evaluate the estimated effectiveness that particular countermeasures and injury mitigation strategies might have for the Australian passenger vehicle fleet. The findings will provide an up-to-date review with specific focus on Australian rollover characteristics that can be used to inform future regulatory and consumer rating tests.

Introduction

Crashes involving rollover have a higher rate of fatal and serious injury than planar crashes in Australia and the United States (US) (Fréchède, McIntosh, Grzebieta, & Bambach, 2011; National Center for Statistics and Analysis, 2007). While the majority of research efforts concerning rollover take place in the US, the characteristics and patterns of rollover crashes and injury outcomes are similar for Australia (Bambach, Mitchell, Mattos, Grzebieta, & McIntosh, 2014). The total number, as well as the rate, of occupants involved in rollover crashes has decreased significantly over the last ten years in New South Wales; however, the rate at which occupants are seriously or fatally injured in rollover crashes has not decreased proportionately (Bambach et al., 2014).

The body regions that most commonly sustain serious injuries in pure rollover crashes are the head, spine, and thorax (Bambach et al., 2014; Mattos, Grzebieta, Bambach, & McIntosh, 2013a). These injuries are caused by the interaction between the occupant and the vehicle interior or exterior environment. It is generally accepted that head and spine injuries are primarily due to direct impact between the head and interior roof structure (Bambach, Grzebieta, Mcintosh, & Mattos, 2013; Foster et al., 2012; Mattos et al., 2013a). In the case of partial ejection the head is exposed to impacts with the ground surface which further increases the risk of injury. Thorax injuries have been reported to occur primarily due to interaction with the vehicle door in oblique-type loading scenarios and are not likely related to the amount of intrusion of the roof or door (Bambach, Grzebieta, & McIntosh, 2013). The omnidirectional nature of the loading conditions during a rollover result in the occupant experiencing a combination of vertical and lateral accelerations which current restraint systems are not designed for.

Advances in vehicle safety technology continue to provide more and better means of reducing occupant injury during a crash through active and passive means (Young, Grzebieta, Rechnitzer, Bambach, & Richardson, 2006), yet no regulatory or consumer rating tests evaluate the performance of passive or active safety features specifically for the rollover crash mode in Australia. Vehicle design, driven by regulatory testing and consumer demand (O'Neill, 2009), has been the primary driver in the recent decline of occupant fatality rates in Australia and the US (Anderson & Searson, 2015; Farmer & Lund, 2015; Newstead, Watson, & Cameron, 2010). Additionally vehicle manufacturers are meeting enhanced requirements more quickly and more widely than ever before (Park, Rockwell, Collins, Smith, & Aram, 2015). It is, thus, advantageous to continue to expand the scope of compliance and consumer rating tests to include new safety technologies, promote innovation, and deliver a greater level of safety.

Methods

This study is a review of injury prevention strategies for rollover crashes that have been identified in the literature. Each strategy is described and its relationship to injuries specific to the head, spine, or thorax is noted. Methods of testing and evaluation are also recommended and the expected benefit of each countermeasure is identified. Current standards or consumer tests are provided as examples where applicable.

The countermeasures reviewed in this work are limited to features that aim to prevent injury during the rollover crash. Therefore, technologies such as electronic stability control that aims to prevent a crash or E-call that aims to provide better post-crash care are not discussed.

Results and Discussion

Four approaches for mitigating head, spine, and thorax injury in rollover crashes were identified from the literature. These are summarised along with their estimated effect on reducing injury to a particular body region in Table 1, where injury is described using the Abbreviated Injury Scale (AIS) (AAAM, 2008). The mitigation of head and spine injuries in rollover crashes requires the use of many different countermeasures and strategies. Thoracic injuries, on the other hand, would benefit the most from an advanced restraint system.

Table 1. Injury risk management objectives for rollover crashes

Strategy	**Estimated injury reduction[1]**		
	Head	**Spine**	**Thorax**
Rollover restraints	Up to 30 % AIS 3+ (Mattos et al., 2013a)	Up to 50 % AIS 3+ (Bambach, Grzebieta, Mcintosh, et al., 2013)	Up to 90 % AIS 3+ (Bambach, Grzebieta, & McIntosh, 2013)
Structural performance	Up to 66 % AIS 3+ (Bambach et al., 2014; Mattos et al., 2013a)	Up to 39 % AIS 3+ (Bambach, Grzebieta, Mcintosh, et al., 2013; Bambach et al., 2014)	Likely unaffected (Bambach, Grzebieta, & McIntosh, 2013; Bambach et al., 2014)
Upper interior head protection	62 % AIS 4+ 30 % head injury as cause of death (NHTSA, 2011a)	Unknown	Likely unaffected (Bambach, Grzebieta, & McIntosh, 2013; Bambach et al., 2014)
Ejection mitigation	25% for ejected occupants (NHTSA, 2011b)		

[1]Based on implementation in current vehicle fleet

Rollover restraints

The seat belt is the most important passive safety technology available in vehicles today; it is credited with saving the lives of over 15,000 passenger vehicle occupants in 2012 in the US alone (Kahane, 2015). Historically, the main function of restraints has been to reduce forward motion during frontal crashes. The primary benefit that restraints provide to rollover occupants is preventing ejection (L. Evans, 1990).

Occupants in a rollover crash undergo a series of discrete inertial and direct loading scenarios due to a combination of free-flight rotation and vehicle-to-ground contact events. With standard restraints occupants can readily contact the upper interior structure of the vehicle (Gloeckner, Bove, Croteau, Corrigan, & Moore, 2007; Moffatt & James, 2005), a common source of head and spine injuries (Bambach, Grzebieta, Mcintosh, et al., 2013; Bedewi, Godrick, Digges, & Bahouth, 2003; Mattos et al., 2013a). Occupants are also subject to lateral loading directions and suffer thoracic injury due to contact with the door, seatbelt or centre console (Bambach, Grzebieta, & McIntosh, 2013; Digges et al., 2013). Advanced restraints are likely to mitigate injury in rollover crashes by reducing occupant excursion and limiting their interaction with the vehicle interior as well as by providing a higher level of support for oblique and lateral loading conditions.

The two main design considerations that can be optimised to prevent unwanted motion include passive features such as seat and restraint geometry, which help to maintain optimal seat position, and active features such as pre-tensioning devices, which reduce the amount of slack available in the system (Hu, Chou, & Yang, 2009). A well-designed belt geometry can reduce occupant excursion significantly by limiting pelvis vertical motion, torso rotation, and maintaining the position of the sash belt over the shoulder (Arndt, Mowry, Dickerson, & Arndt, 1995; Bostrom & Haland, 2005; Meyer, Oliver, Hock, & Herbst, 2010; Moffatt, Cooper, Croteau, Parenteau, & Toglia, 1997; Rains, Elias, & Mowry, 1998; Sword &

Sullivan, 2007; Ward, Der Avanessian, Ward, & Paver, 2001; White et al., 2011). Active restraints currently require the use of pyrotechnic, motorised, or mechanical devices to limit slack in the belt system. The use of such systems has proven to be effective in reducing excursion in experimental tests (Hu et al., 2009; Meyer, Davis, Chng, Herbst, & Forrest, 2000; Rains et al., 1998; Sword & Louden, 2009; Sword & Sullivan, 2007); however they rely on very early activation times to be optimally beneficial (Hare et al., 2002; McCoy & Chou, 2007; Moffatt et al., 1997; Newberry et al., 2006). Motorised retractors are likely the current best option for removing belt slack early in an event as they can deploy prior to significant occupant loading and can be reversed in the case of a non-event (Schoneburg, Paurevic, Fehring, Richert, & Bogenrieder, 2015).

Testing and evaluation: rollover restraints

A method to evaluate the performance of restraint systems in the rollover crash mode must assess multiple criteria. This is highlighted by the difference in the experimental and field performance of some promising restraint systems. For example, seat integrated restraints (SIR) have shown promising results in the laboratory (Bostrom, Haland, & Soderstrom, 2005), yet these results have not been supported by real world data (Haaland, 2013; Padmanaban & Burnett, 2008). A general outline for a systematic evaluation method is given in Table 2 where recommended evaluation methods and criteria for each attribute of a restraint system are proposed. The table describes general response requirements without quantifying them, as the requirements would have to be determined in conjunction with the specific test procedures used to evaluate them. Three subsystem tests may be required to evaluate the entire system; one to evaluate sensor activation, one to evaluate restraint performance under rollover conditions, and one to evaluate thorax injury due to primarily lateral motion.

Activation times are already assessed by the Australasian New Car Assessment Program (ANCAP) using the manufacturers test data (ANCAP, 2014). Additional tests as required could be implemented using physical tests or numerical models to determine the activation times in critical pre-rollover events (Berg, Rucker, & Kroninger, 2007; Gugler & Steffan, 2006; Ridella, Altamore, & Nayef, 2001). It is important to note that rollover sensors are expected to deploy with sufficient time to be effective for 84 % of rollover crashes (Lange, Iyer, Pearce, Jacuzzi, & Croteau, 2011). It is not currently possible to predict the remaining 16 % of rollover crashes early enough for the deployment of interior safety features to have a significant effect. This is due to their being caused by vehicle-to-vehicle or fixed-object collisions that have much shorter rollover initiation times. A rating scheme could possibly give higher rating for features that are reversible and allow for earlier deployment or deployment in cases that are not covered by go/no-go sensors.

Table 2. General recommendations for restraint assessment criteria

Characteristic	Evaluation method	Proposed criteria for better performance	Example technology
Active restraint deployment time	• On-road manoeuvres of critical pre-crash scenarios (Eigen & Najm, 2009; Ridella et al., 2001) • Numerical simulation (Berg et al., 2007; Gugler & Steffan, 2006) • Manufacturers data (ANCAP, 2014)	• Prior to significant belt loads • Earlier activation time • Non-hazardous result for false-positive	• Motorised retractors (Schoneburg et al., 2015) • Rollover sensors (Cassatta et al., 2011)
Belt slack removal and occupant excursion	• Repeatable impact test (Chirwa, Stephenson, Batzer, & Grzebieta, 2010; Chou, McCoy, & Le, 2005) • Inverted drop (D. Friedman & Chng, 1998) • Component tests (Sword & Sullivan, 2007)	• More slack removed • Non-injurious belt loads • Reduced vertical/lateral motion • Lower head contact force • Critical contact locations	• Pre-tensioner (White et al., 2011) • Motorised retractors (Schoneburg et al., 2015) • SIRS (Meyer et al., 2010) • 3+2 pt belt (Bostrom & Haland, 2005)
Lateral/oblique loading	• Sled tests (Humm et al., 2015) • Side impact with far-side ATD/Criteria (Fildes & Digges, 2009)	• Meet thoracic injury criteria	• Front centre airbag (Thomas, Wiik, & Brown, 2013) • Torso airbag (Bostrom et al., 2005)

Many different methods have been used to assess the effectiveness of restraints under simulated rollover conditions including spit tests (i.e. pure rotation of a vehicle without impact) (Meyer et al., 2010; Moffatt et al., 2003), component tests with rotation and inverted impact (Sword & Sullivan, 2007), full scale rollover tests (White et al., 2011), or inverted drop tests (D. Friedman & Chng, 1998). The use of a dynamic component test method has many advantages, including the ability to replicate actual rollover conditions and allow for simultaneous evaluation of other interior countermeasures (Cassatta et al., 2010). However, the complexity and cost of performing such tests may hinder the repeatability of such methods.

Finally, the performance under lateral and oblique loading scenarios could readily be evaluated in a sled test or in conjunction with side impact tests using an appropriate far-side anthropomorphic test device (ATD) (Fildes & Digges, 2009). More work is necessary to develop performance metrics and a more biofidelic ATD as current ATDs do not replicate human-to-restraint motion for non-frontal loading directions, especially with regard to thorax injury (Fildes et al., 2002; Kent, Patrie, & Benson, 2003; Ward et al., 2001).

Benefit to rollover occupants: rollover restraints

It is hard to calculate the direct benefit that advanced restraints would provide to occupants involved in rollover crashes. They are expected to have a large benefit to multiple body regions. This is because over 75 % of serious injuries sustained due to a rollover occur to the head, spine or thorax, which are the body regions that would be advantaged the most by an advanced restraint system (Bambach, Grzebieta, & McIntosh, 2013; Bambach, Grzebieta, Mcintosh, et al., 2013; Mattos et al., 2013a).

Structural Performance

The severity of roof intrusion in a rollover crash is a function of a vehicle's roof strength (NHTSA, 2010; Young & Grzebieta, 2010). Roof strength is also independently associated with the rate of injury in rollover crashes; a 20 per cent reduction in the injury rate is predicted for each 1 unit increase in vehicle roof strength-to-weight ratio (SWR) (Brumbelow & Teoh, 2009; Brumbelow, Teoh, Zuby, & McCartt, 2009). Roof intrusion has been shown to be associated with non-ejected occupant injury in general (Conroy et al., 2006; Mackay & Tampen, 1970), and head and spine injury specifically (Austin, Hicks, & Summers, 2005; Bedewi et al., 2003; Dobbertin, Freeman, Lambert, Lasarev, & Kohles, 2013; Freeman, Dobbertin, Kohles, Uhrenholt, & Eriksson, 2012; D. Friedman & Friedman, 1998; Hu, Cho, Yang, & King, 2007; Huelke, Lawson, & Marsh Iv, 1977; Mandell, Kaufman, Mack, & Bulger, 2010; Rains & Kanianthra, 1995; Strashny, 2007; Terhune, 1991). While correlation between the two does not imply causation, as highlighted by the serious head and spine injuries observed to occur in rollovers with minimal roof intrusion (Bambach, Grzebieta, Mcintosh, et al., 2013; Mattos et al., 2013a), limiting the amount of structural deformation during a crash is fundamental to providing a safe environment for the occupant (De Haven, 1952). This is partly due to ensuring that interior restraint systems are able to perform as effectively as possible without being obstructed by intruding components. Further, roof intrusion has been reported by emergency services to hinder the extrication of occupants which reduces the effectiveness of post-crash care (Mattos, Grzebieta, Bambach, & McIntosh, 2013b).

Testing and evaluation: structural performance

In reviewing the feasibility of implementing an Australian Design Rule (ADR) with regard to roof strength Henderson and Paine concluded that an improvement in roof strength, along with other countermeasures, would increase the safety of vehicles in a rollover (Henderson & Paine, 1998). They could not, however, recommend the use of the original US roof strength standard, i.e. Federal Motor Vehicle Safety Standard (FMVSS) number 216, as it was seen as inadequate at the time. Since then the FMVSS 216 has been updated to require a SWR of 3, instead of 1.5, in a two-sided, rather than one-sided, test (NHTSA, 2009). Additionally the Insurance Institute of Highway Safety (IIHS) has implemented a rating system that requires a

SWR of 4.0 or greater for a vehicle to receive a good rating (IIHS, 2009). The IIHS model was scheduled for implementation by ANCAP, but was withdrawn in 2013 (ANCAP, 2015).

Many test methods have been proposed to evaluate roof strength for passenger vehicles. The most appropriate, based on repeatability and replication of real-world deformation patterns, include the quasi-static roof strength test, the inverted drop test, and the Jordan Rollover System (JRS) or equivalent Dynamic Rollover Test System (DRoTS) (Chirwa et al., 2010; Gugler & Steffan, 2006; Kerrigan et al., 2011). Two categories of test methods, along with proposed criteria, are summarised in Table 3. While JRS and DRoTS tests are more complicated to run they have the additional advantage of providing a dynamic environment in which the entire vehicle, inclusive of all its features and countermeasures, can be assessed in conjunction with the structural performance. These features and countermeasures include those discussed in this paper as well as other design choices that may indirectly affect occupant safety such as interior roof shape and door panel stiffness.

Benefit to rollover occupants: structural performance

The head and spine, specifically the cervical and upper thoracic regions, are affected the most by structural deformation of the roof. It is estimated that up to 66 % of AIS 3+ head injuries and up to 39 % of AIS 3+ spine injuries are associated with roof intrusion (Bambach, Grzebieta, Mcintosh, et al., 2013; Bambach et al., 2014; Mattos et al., 2013a). Thoracic injuries, however, do not appear to be related to the amount of intrusion that occurs to the adjacent roof or door during a rollover crash (Bambach, Grzebieta, & McIntosh, 2013). The overall injury rate due to rollover crashes may further be reduced in vehicles that have better structural performance if it allows for easier extrication by emergency services (Mattos et al., 2013b).

Table 3. General recommendations for structural performance criteria

Method	**Recommended criteria**
Quasi-static (i.e. FMVSS 216)	• Strength-to-weight ratio • Door performance (i.e. ease of opening)
Dynamic (i.e. inverted drop, JRS, DRoTS)	• Roof intrusion • Roof intrusion speed • Ejection portal creation • Door performance • Effect of deformation on other countermeasures

Upper interior head protection

The greatest risk of head injury in rollover crashes is due to direct contact between the head and the upper interior roof of the vehicle (Mattos et al., 2013a, 2013b). The most straightforward technique used to reduce the risk of head injury from these contacts is to increase the compliance of the upper interior structure via use of energy absorbing components such as honeycomb-type structures or even roof-mounted airbags (Heudorfer, 2005; Seong, Park, & Woo, 2002). These techniques are most effective in combination with greater roof strength. Vehicles in the US and Australia have been required to meet general interior protection standards since 1968 and 1989, respectively (Department of Infrastructure and Transport, 2006). In 1999 the US extended the FMVSS no. 201 to include upper interior head protection (NHTSA, 2013). The extension of the rule is now referred to as FMVSS 201U. The added cost of implementing the head protection countermeasures, including additional lifetime fuel costs due to the added weight of the system, to each vehicle has been estimated to be approximately 25 USD (NHTSA, 2011a).

Testing and evaluation: head protection

Compliance testing consists of firing a free motion headform at predetermined locations on the upper interior vehicle roof structure (NHTSA, 1998). The US standard, FMVSS 201U, requires that the Head Injury Criterion (HIC) value resulting from the impact not exceed 1000 (NHTSA, 2013). HIC values have decreased from an average of 909.0 in pre-FMVSS 201U standard US vehicles to 667.5 in post-standard vehicles (NHTSA, 2006). A rating system could easily be developed based on the US model in which either a pass/fail criterion was set or more points were awarded for lower injury measures.

Benefit to rollover occupants: head protection

The countermeasures are estimated to reduce AIS 4+ head injuries due to upper interior contact in rollover crashes by up to 62 % in the US and are expected to have a similar benefit in Australia (Mclean et al., 1997). There is, however, the potential for increased padding to merely shift injuries from the head to the spine as it would increase the ability of the head to ‘pocket’ resulting in a head-neck constraint that increases the risk of spinal fractures (Nightingale, Richardson, & Myers, 1997), though this could be minimised by reducing the friction of the surface (Hu, Yang, Chou, & King, 2008).

Ejection mitigation

Occupants that are ejected during a rollover crash are more than 3 times as likely to be fatally injured than those that remain inside the vehicle (El-Hennawy et al., 2014). Full ejection is almost entirely prevented with the use of a standard restraint system, even in older vehicles without modern restraints (Huelke, Marsh Iv, Dimento, Sherman, & Ballard, 1973). However, partial ejection can still occur to restrained occupants (Parenteau & Shah, 2000). Thus, additional safety systems such as rollover-activated side curtain airbags with long-duration inflators (Cuerden, Cookson, & Richards, 2009; Eigen, 2003; N. C. Evans & Leigh, 2013; Rechnitzer & Lane, 1994), and laminated side window glazing (Batzer et al., 2007; Malliaris, DeBlois, & Digges, 1996; Sances, Carlin, & Kumaresan, 2002; Willke et al., 1999) combined with a reduction in roof intrusion (K. Friedman, Hutchinson, Mihora, & Cummings, 2015; Moffatt & Padmanaban, 1995) are required to prevent partial ejection of the head, torso, and upper extremities by eliminating ejection portals.

Testing and evaluation: ejection mitigation

Methods currently used to evaluate the ability of a system to prevent ejection, such as those employed by the FMVSS No 226 in the US, include deploying a headform into the countermeasure, which is typically a rollover-activated side air curtain, and measuring its excursion beyond the window frame (NHTSA, 2011b). The performance could be rated based on pass fail criterion such as a set excursion distance or in conjunction with select impact energy levels (e.g. a higher rating for preventing excursion at a higher impact energy level) (Dix et al., 2010). The algorithms used to deploy the ejection mitigation countermeasures, which are also responsible for firing the active restraints, could be assessed as described in Table 2.

Benefit to rollover occupants: ejection mitigation

The primary portals through which rollover occupants are ejected include the front side windows (Malliaris et al., 1996). By preventing partial or full ejection through these portals up to 18 % of injuries sustained by belted occupants and 49 % of injuries sustained by unbelted occupants can potentially be prevented (Bedewi et al., 2003). A preliminary analysis of the benefit of rollover-activated side airbags indicates a 41 % reduction in fatalities due to rollover crashes (Kahane, 2014).

Conclusions

Four approaches to reducing injury in rollover crashes through the use of passive and active safety features have been reviewed in light of recent findings regarding head, spine, and thorax injury. All of the approaches and estimated benefits are supported by real world evidence and are expected to provide similar benefit to Australia.

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Review of South Australia's fixed and mobile speed camera programs

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Abstract

The use of mobile and fixed speed detection devices has long been a contentious issue. Traffic Intelligence and Planning Section of South Australia Police has conducted a review of the value of South Australia's mobile and fixed speed camera programs. As part of the review, the following factors were taken into consideration: the potential under-reporting of speed as a contributor to fatal crashes; the number of serious injury and fatal crashes excessive speed has caused or contributed to over the last 14 years; the rate of motorist compliance with speed limits over the last six years; demographics of fatal speeders; speed detection hours worked and differences in legislation across the States and Territories. The review compared the rate of speed detection across the speed detection devices used by South Australia Police. A comparison of crash and casualty data pre and post-fixed speed camera installation was conducted across six sites.

There are multiple confounding factors which interact to influence driver behaviour. Nonetheless, one of the key findings of this review is speed detection deployments increase driver speed compliance and reduce the incidence of speed-related fatalities and serious injuries.

Introduction

There are a variety of methods used to detect speeding motorists. Each method has unique benefits and limitations. The purpose of the fixed safety camera network is to ensure speed limit compliance at black spots. The purpose of mobile speed cameras is to detect speeding motorists and to create a general speeding deterrent across the entire road network. **South Australia Police (SAPOL)** has been using mobile speed cameras since 1990. Advanced speed camera technology was introduced in 1999. In 2001, South Australia introduced fixed dual speed and red light cameras to the road network. Although these dual purpose cameras were rolled out in 2001, they were not used for speed enforcement until 15/12/2003 (Kloeden, Edwards, & McLean, 2009).

Point-to-point (P2P) speed cameras measure the time vehicles take to travel between two sites on a road and calculate the average travelling speed over the length of road to see if the motorist was speeding. Fixed P2P cameras have been activated on the Dukes Highway, Port Wakefield Road and Victor Harbor Road over the last year. Additional point-to-point cameras will soon be operational on the Sturt Highway, South Eastern Freeway and the Northern Expressway.

This paper examines the effect speed detection systems have on the road toll, which devices are most effective and puts forward issues for future planning and consideration.

Impact of speed on the road toll

SA Government website mylicence.sa.gov.au states that speeding and inappropriate travel speeds are estimated to directly contribute to at least 35% of deaths on SA's roads each year (Department of Planning, Transport and Infrastructure, 2015). **Traffic Intelligence and Planning Section** (**TIPS**) data indicates that excessive speed was the joint fourth (with alcohol) police nominated cause of 2014's fatal crashes. While excessive speed contributed to a notable portion (19%) of last year's fatal crashes, TIPS data indicates due care (29%), drugs (24%) and distraction (23%) were the leading causes of fatal crashes in 2014. Driver error 'due care' includes collisions that occurred at inappropriate travel speeds for the driving conditions. For example, a driver who crashes whilst travelling at the speed limit when there is strong wind and heavy rain would be classified as driving without due care rather than speeding. It should be noted that the cause of a crash is sometimes difficult to assess. In many cases, speeding may be a contributing factor but not formally acknowledged. It is therefore likely speeding as a cause is underestimated.

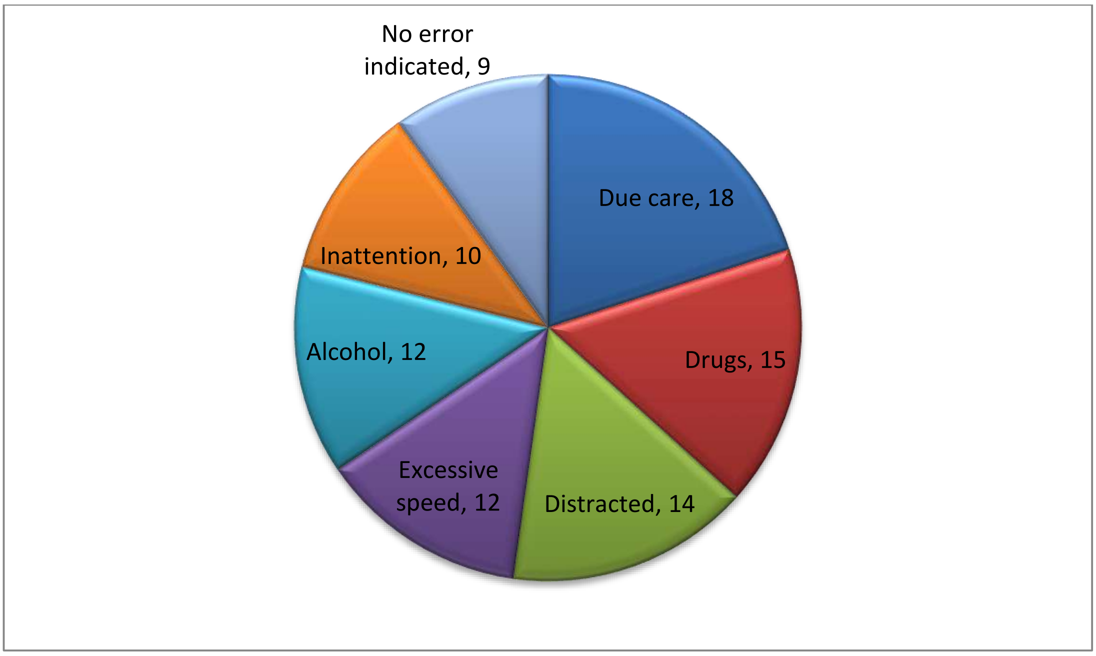

Figure 1: Driver errors that contributed to fatal crashes in 2014
Data from 13/03/2015 Business Objects report

Figure 2 shows the downward trend in crashes resulting in fatalities and serious injuries that had excessive speed as a driver error.

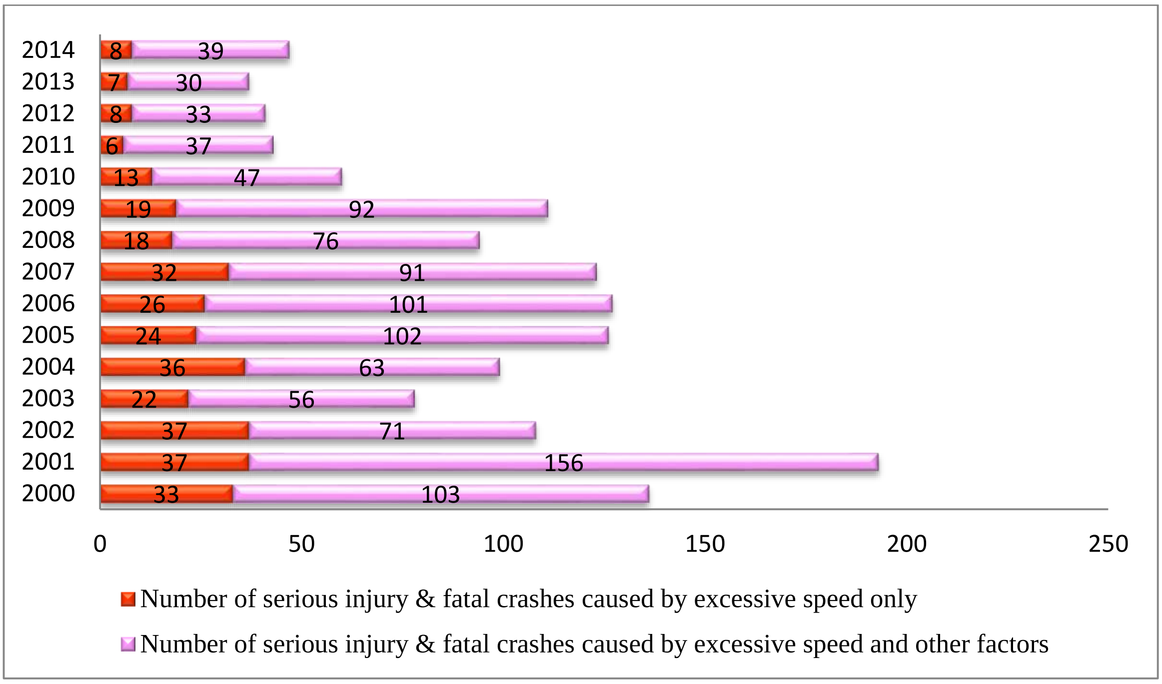

Figure 2: Serious injury & fatal crashes caused by excessive speed
Data from 13/03/2015 Business Objects report

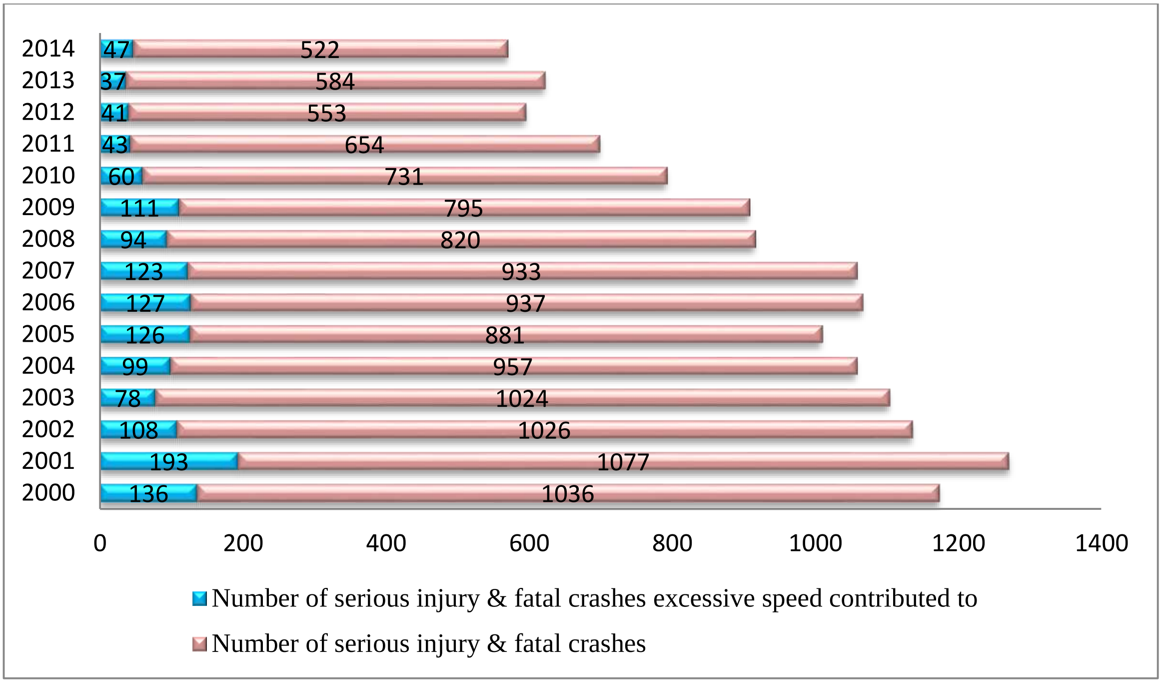

Figure 3: Speed as a contributor to serious injury & fatal crashes
Data from 13/03/2015 Business Objects report

The reduced number of serious injury and fatal crashes to which speed contributed between 2011 and 2013 coincides with an increase in speed detection hours and a corresponding increase in driver speed compliance (see Figures 3 and 8).

Notwithstanding enhancements in vehicular safety and road design, this demonstrates that SAPOL speed detection deployments increase driver speed compliance and reduce speed-related fatalities and serious injuries.

Mobile speed camera use in NSW

In 2008, road crash fatalities in NSW had declined for six consecutive years. In December 2008, NSW phased out the use of its ageing wet film mobile speed cameras and became the only state or territory in Australia to no longer use mobile speed cameras. Between 2008 and 2009, NSW's road toll jumped from 374 to 453 – an increase of 21%. As shown in Figure 4, the 2008 road toll was well below the linear trend line. When mobile speed cameras ceased operation, the road toll did more than regress to the mean – it shot well above the mean. This indicates that the removal of mobile speed cameras from NSW's road safety initiatives directly contributed to an increase in crash fatalities.

On 19/7/2010, in response to the soaring road toll, the NSW Government Roads and Maritime Services (then the Roads and Traffic Authority) began operation of six digital mobile speed cameras. Since then, the NSW road toll has more closely followed the downward trend line.

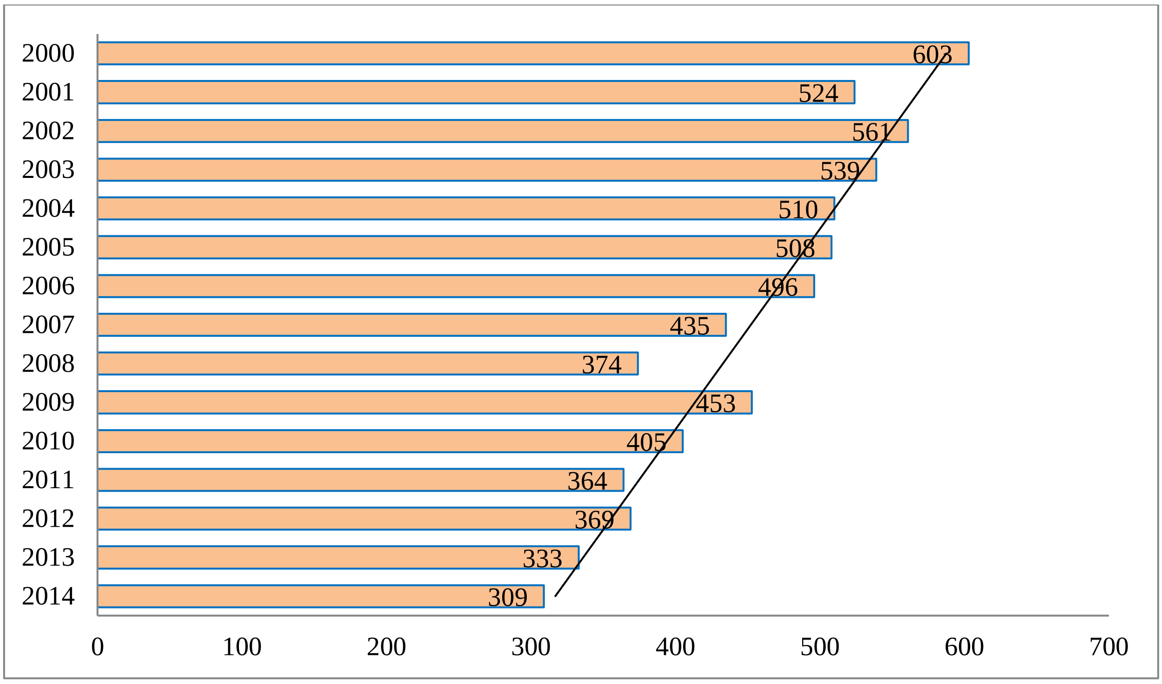

Figure 4: NSW Crash Fatalities
Source: NSW Government Centre for Road Safety

Centre for Automotive Safety Research evaluation of the SA default 50 km/h speed limit

On 1 March 2003, the default urban speed limit in South Australia was reduced from 60 km/h to 50 km/h. In the year following the change in the default speed limit, the **Centre for Automotive Safety Research (CASR)** found that on roads where the speed limit was reduced from 60 km/h to 50 km/h:

- The average travelling speed fell by 2.3 km/h
- The average free travelling speed[1] fell by 2.2 km/h
- The number of casualty crashes fell by 20% (330 fewer casualty crashes)
- The number of people injured in crashes fell by 24% (495 fewer casualties)
- The number of people needing treatment by a private doctor fell by 16% (103 fewer cases)
- The number of people needing treatment at a hospital fell by 29% (352 fewer cases)
- The number of people needing admission to hospital fell by 13% (34 fewer cases)
- The number of people fatally injured fell from 14 to 8 (Kloeden et al, 2009).

The reduction in casualties in the year after the default urban speed limit changed is estimated to have saved the South Australian community at least $39,384,282 ($30 million in 2004 dollars)[2] (Kloeden et al, 2009).

[1] Free travelling speed = the speed of vehicles that are travelling at least 4 seconds behind the vehicle in front of them.
[2] Calculated using the Bureau of Transport Economics (2000) human capital method updated to 2004 dollars.

On roads where the speed limit remained at 60 km/h:

- The average travelling speed fell by 0.9 km/h
- The average free travelling speed fell by 0.7 km/h
- The number of casualty crashes fell by 5% (165 fewer casualty crashes)
- The number of people injured in crashes fell by 7% (327 fewer casualties)
- The number of people needing treatment by a private doctor fell by 3% (48 fewer cases)
- The number of people needing treatment at a hospital fell by 10% (240 fewer cases)
- The number of people needing admission to hospital fell by 6% (30 fewer cases)
- The number of people fatally injured fell from 35 to 26 (Kloeden et al, 2009).

This further reduction in casualties in the year after the default urban speed limit changed is estimated to have saved the South Australian community at least $42,009,901 ($32 million in 2004 dollars) (Kloeden et al, 2009).

For this study, CASR compared vehicle on-road speeds just before the default limit was introduced with speeds one year after the introduction of the default speed limit. CASR's data shows the reduced default speed limit contributed to a reduction in casualty crashes, injuries and fatalities. It also created a diffusion of benefit to other roads.

The impact of fixed speed cameras on crash frequency and severity

For the purposes of this review, TIPS has assessed the performance of a sample of six fixed speed cameras at various locations in Adelaide:

- Glover Ave, ADELAIDE. Fixed mid-block camera installed 25/5/2010.
- Glynburn Rd and Kensington Rd intersection, ERINDALE/KENSINGTON GDNS/KENSINGTON PK/LEABROOK. Fixed camera installed 25/3/2009.
- North Tce and Frome Rd intersection (Botanic Rd and Frome St also analysed), ADELAIDE. Fixed camera installed 11/3/2009.
- Montefiore Rd and War Memorial Drive intersection, NORTH ADELAIDE. Fixed camera installed 20/1/2009.
- Marion Rd and Sturt Rd, BEDFORD PARK/MARION/MITCHELL PARK/STURT. Fixed camera installed 20/1/2009.
- Anzac Hwy and Cross Rd, PLYMPTON. Fixed camera installed 24/11/2008.

Five years' crash and casualty data from immediately before and immediately after camera installation were taken for five of the sites, and four years and eleven months' data for the more recently installed Glover Avenue site. Data sets were analysed for the roads and suburbs the speed cameras are located in, which is the closest possible crash location parameter to the speed cameras. Crash and casualty data for both roads were analysed for fixed speed cameras located at intersections.

It is beyond the scope of this paper to directly compare statistics between sites with fixed speed cameras with equivalent sites without permanent cameras. Such a comparison would require matching sites based on factors such as the width of the road shoulder, the number of lanes in the road or any designated overtaking lanes, road condition and alignment, the traffic flow, and speed limits.

The range of variables precludes making valid direct comparisons between specific sites. However, more general inferences can be drawn and trends have been identified.

When comparing data from before and after fixed speed camera installation at the six random sites analysed by TIPS there was an overall:

- 60% decrease in fatal crashes (from 5 to 2)
- 71% reduction in fatalities (from 7 to 2)
- 20% reduction in crashes resulting in at least one person being admitted to hospital (from 69 to 55)
- 32% reduction in admissions to hospital (from 81 to 55)
- 6% reduction in all casualty crashes (from 689 to 648)
- 14% reduction in all crashes (from 6066 to 5207).

The reduction in serious injuries and fatalities exceeds the reduction in overall serious injury and fatal crashes. In South Australia, a serious injury crash results in at least one person spending one or more nights in hospital. In the five year period post-fixed speed camera installation, the ratio of fatal crashes to fatalities was 1:1. The ratio of serious injury crashes to actual hospital admissions was also 1:1. Prior to speed camera installation, 1.17 people were admitted to hospital per serious injury crash and there were 1.4 deaths per fatal crash. Since the installation of fixed speed cameras on the six sites analysed for the purposes of this paper, there has been a significant reduction in serious injuries, fatalities and serious injury crashes on the roads in the suburbs where the cameras are located.

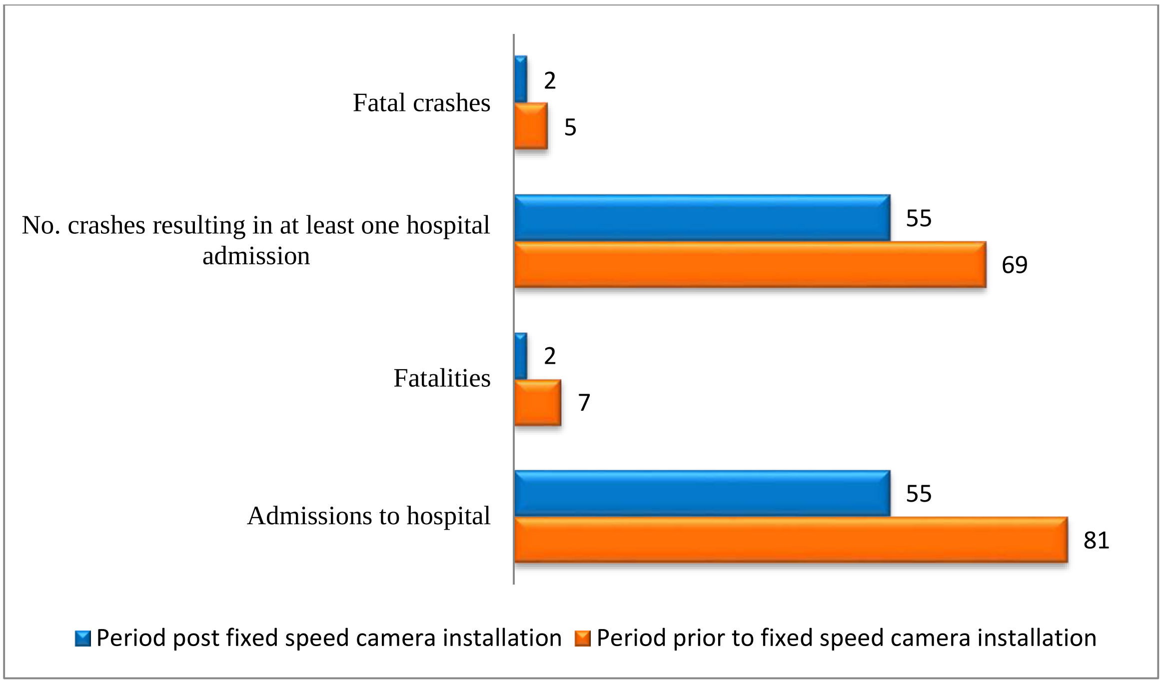

Figure 5: Serious injury & fatal crash data before and after fixed speed camera installation across 6 sites

Source: Business Objects crash and casualty reports

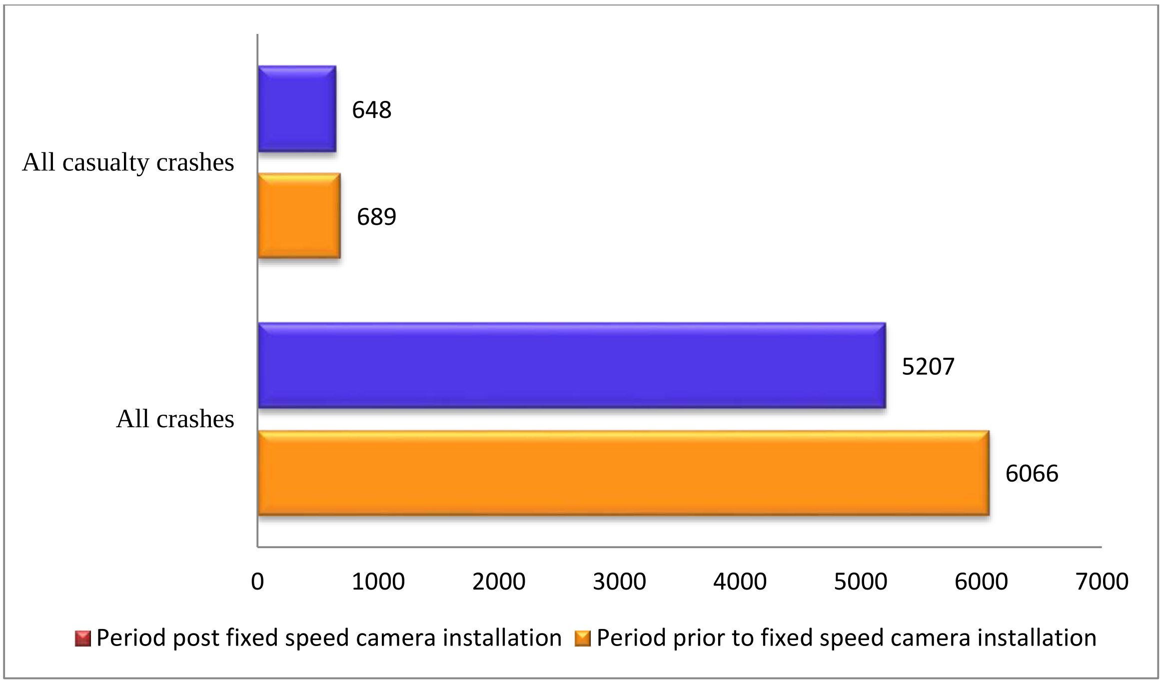

Figure 6: All crash & casualty data before and after fixed speed camera installation across 6 sites

Speed cameras save lives and money

The **Bureau of Transport and Regional Economics (BTRE)** 2010 (most recent) estimated road crash costs are as follows.

Estimated losses by injury outcome:

- $2.4 million for a road fatality
- $214,000 for a hospitalised injury (including disability-related costs)
- $2,100 for a non-hospitalised injury.

Estimated losses for each disability case:

- $3.82 million for each case of profound impairment
- $1.78 million for each case of severe impairment
- $542,000 for each case of moderate impairment
- $126,000 for each case of mild impairment.

The estimated costs on a crash basis were:

- $2.67 million per fatal crash
- $266,000 per crashes resulting in at least one hospitalised injury
- $14,700 per crash resulting in at least one non-hospitalised injury
- $9,950 per property damage only crash (Risbey, de Silva, & Cregan, 2010).

Based on the above estimates, the six fixed speed cameras analysed in this paper have contributed to saving the South Australian community at least $19,387,109 (indexed for CPI: $17,564,000 in 2010 dollars) (Reserve Bank of Australia, 2015):

- $13,245,577 ($12 million in 2010 dollars) over five years for the reduction in fatalities
- $6,141,532 ($5,564,000 in 2010 dollars) over five years for the reduction in hospital admissions.

Non-hospitalised injuries have not been considered for the purposes of this paper.

Rate of non-compliance

Mobile speed cameras' speed detection rate as a percentage of passing vehicles for the 2013-14 financial year was almost 20 times greater than fixed cameras' (0.78% vs 0.04%). This indicates that motorists generally know where fixed speed cameras are and are more likely to obey the speed limit if they are aware their speed is being monitored. Nonetheless, Figure 7 shows the trend of an increasing percentage of motorists complying with speed limits across the road network. Data indicates that both fixed and mobile speed cameras have a positive impact on driver speed compliance.

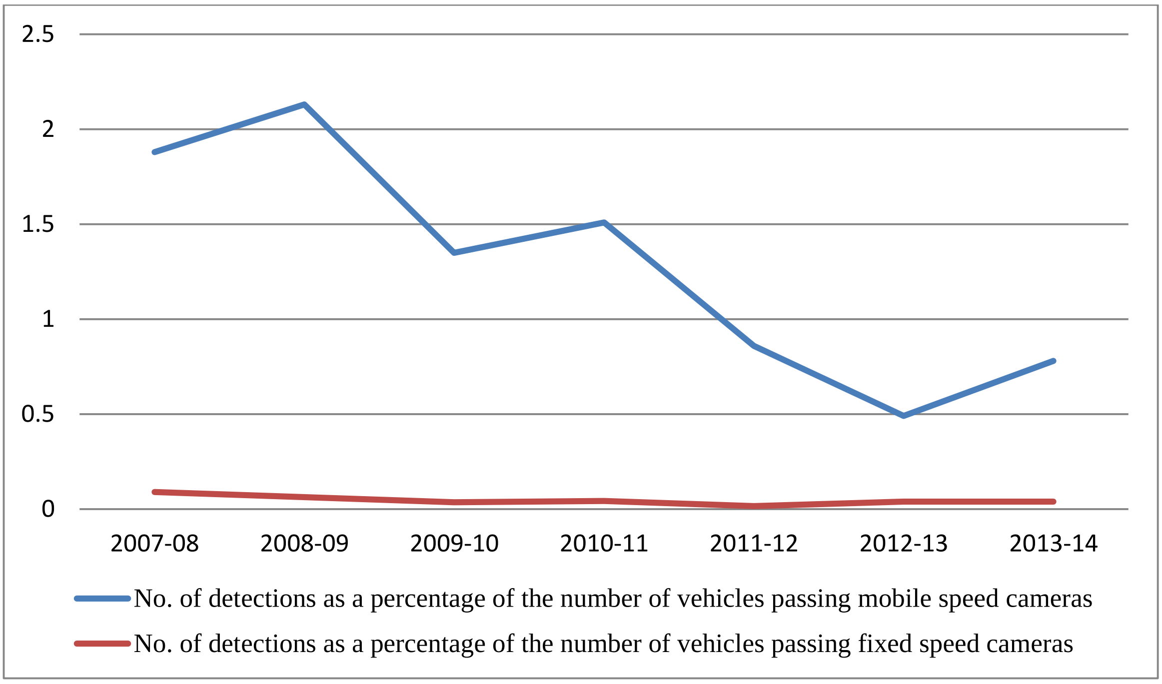

Figure 7: Speed detections as a percentage of all traffic
Source: SA Government Portfolio Statements 2010-2014

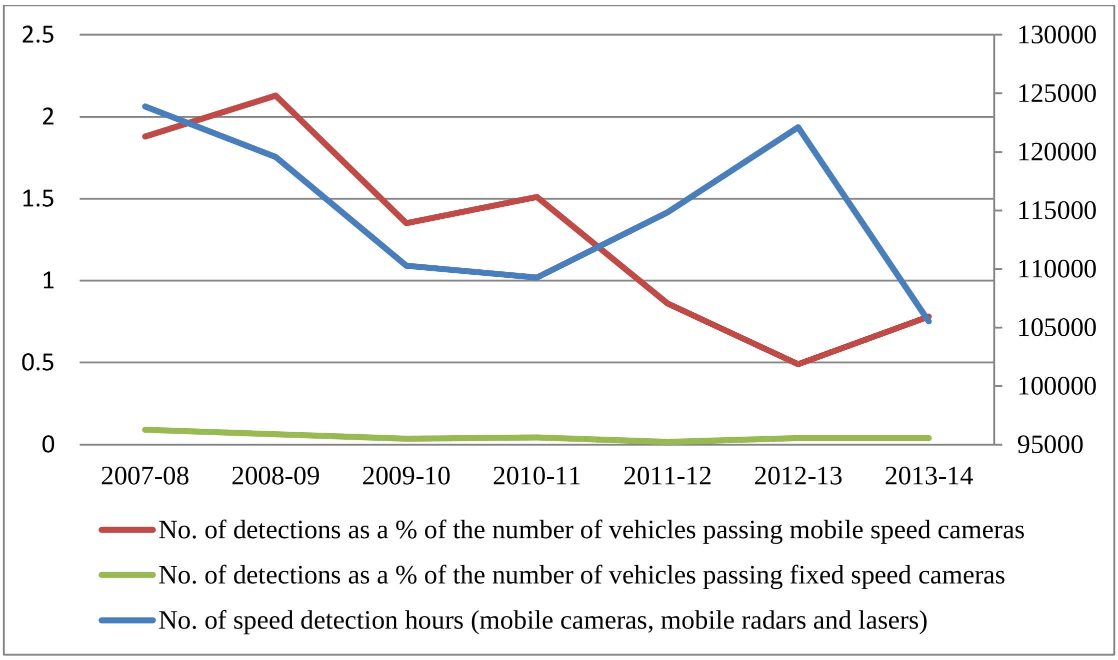

Figure 8: Impact of speed detection activity on rate of non-compliance
Source: SA Government Portfolio Statements 2010-2014 and Business Objects deployment data

Figure 8 shows the interaction between the mobile speed camera rate of detection and number of speed detection hours from 1/7/2007 to 30/6/2014. In this seven year period:

- In the three years that the proportion of motorists caught speeding increased year on year (1/7/2007-30/6/2008, 1/7/2009-30/6/2010 and 1/7/2012-30/6/2013), there had been a corresponding reduction in speed detection hours worked.
- In the six years for which comparable data is available, the number of speed detection hours only increased year on year for the two year period 1/7/2010-30/6/2012. In the same period, the number of detections as a percentage of the number of vehicles passing mobile speed cameras decreased from 1.51% to 0.86% to 0.49%.
- 1/7/2008 – 30/6/2009 is the only period in which both speed detection hours and the proportion of motorists caught speeding decreased.

The above points demonstrate a relationship between speed detection hours worked and speed limit compliance. The more police are seen to be enforcing speed limits (deployment hours), the more motorists comply with speed limits.

Demographics of fatal speeders

Of the 12 fatal crashes that had Excessive Speed listed as one of the driver errors in 2014 (see Appendix):

- 33% (4) were disqualified (3) or unlicensed (1) drivers
- 33% (4) of the fatalities were motorcyclists
- At least 38% (3) of the car fatalities were not wearing a seatbelt
- 92% (11) of the drivers / motorcyclists were male
- 67% (8) were aged between 26 and 35
- 67% (8) of the crashes occurred in rural areas
- 67% (8) had BAC ≥0.105 (4 category 2, 4 category 3)
- 58% (7) tested positive for illicit drugs. This number may rise as more forensic results are returned to SAPOL
    - 2 tested positive for methylamphetamine
    - 3 tested positive for **tetrahydrocannabinol (THC)**
    - 2 tested positive for THC and methylamphetamine.

SAPOL addresses the above listed driver behaviours, which are known to co-occur with speeding, through the use of **Mobile Automatic Number Plate Recognition (MANPR)** and various Operations on drink and drug driving, seatbelt use and motorcyclists. Ongoing partnerships with other road safety stakeholders will ensure best practice in approaching multi-faceted, problematic driving behaviours.

Enforcement

TIPS data shows that mobile radar is the most frequently used speed detection device in country areas whereas mobile speed camera is the most frequently used device in metro areas. Mobile speed cameras result in more **General Expiation Notices** (**GEN**s) issued per hour than any other speed detection device. Other speed detection devices are disadvantaged by a reduction in detection hours by police contact with drivers.

Apparatus	Country hours	Metro hours	Total
Handheld radar	390	96	**486**
Laser	9,922	6,429	**16,350**
Mobile radar	38,259	329	**38,588**
Mobile speed camera	15,509	29,526	**45,034**
TOTAL	**64,079**	**36,380**	**100,459**

Table 1: Speed detection hours 2014
Source: Business Objects report run 31/3/2015
*Figures have been rounded off to the nearest whole number. This data is indicative only.

Apparatus	Country	Metro	Overall
Handheld radar	0.29	0.86	**0.41**
Laser	0.53	0.77	**0.62**
Mobile radar	0.24	0.35	**0.24**
Mobile speed camera	1.63	2.29	**2.06**
Average	**0.62**	**2.00**	**1.12**

Table 2: GENs issued per hour - 2014
Source: Business Objects report run 31/3/2015
*Figures have been rounded off to two decimal points. This data is indicative only.

Legislation

On 1/9/2012, penalties for low level speeding in South Australia changed to lower expiation fees and increased demerit points. Both demerit points and expiation fees were increased for higher level offences (Department of Planning, Transport and Infrastructure, nd).

The reduced expiation fee for low level offending coincides with a 59% rise in the proportion of motorists speeding between 2012-13 and 2013-14. This indicates that the increase in demerit points alone for low level speed offences is not an effective deterrent.

Victoria has the second lowest rate of annual fatalities per 100 million **vehicle kilometres travelled** (**VKT**), after the Australian Capital Territory (**ACT**) (BITRE, 2014). Victoria also has the second lowest annual fatality rate per 100,000 population, again after the ACT (BITRE, 2014). The size of South Australia and length of its rural road network is more comparable to Victoria than the ACT. Victoria has three more speeding offence speed categories than South Australia. Victoria also introduces immediate licence disqualification for motorists caught exceeding the speed limit by ≥25 kph, or travelling at ≥130 kph in a 110 kph speed zone. New South Wales disqualifies drivers who are convicted of exceeding the speed limit by 30 kph. South Australia only has immediate loss of licence for six months for drivers caught travelling at 45 km/h or more above the speed limit.

The Bureau of Infrastructure, Transport and Regional Economics VKT and annual fatality rate data indicates South Australia would benefit from a realignment of its dangerous driving speed to more closely match Victoria's.

Key facts

- The leading causes of 2014's fatal crashes were: due care (29%), drugs (24%), distraction (23%), speeding (19%) and alcohol (19%).
- NSW's annual road toll increased by 21% (from 374 to 453 fatalities) in the year following cessation of mobile speed camera deployments. Prior to that, there had been six successive years of declines in crash fatalities.
- When comparing data from before and after fixed speed camera installation at the six random sites analysed by TIPS there was an overall:
    - 60% decrease in fatal crashes (from 5 to 2)
    - 71% reduction in fatalities (from 7 to 2)
    - 20% reduction in crashes resulting in at least one hospital admission (from 69 to 55)
    - 32% reduction in admissions to hospital (from 81 to 55).

Key findings

- Speed detection deployments increase driver speed compliance and reduce the incidence of speed-related fatalities and serious injuries.
- Lowering a road's speed limit increases driver speed compliance on other roads in the network.
- Fixed speed cameras have contributed to reducing the number of fatal crashes, fatalities, serious injury crashes and admissions to hospital across the locations analysed by TIPS.
- Mobile speed cameras have the highest detection rate of all speed detection devices due to their changes in location. They also benefit from no reduction in detection hours due to police contact with drivers.
- There is a demonstrated inverse relationship between speed detection hours worked and motorist rate of non-compliance.
- Mobile radar is the most frequently used speed detection device in country areas whereas mobile speed camera is the most frequently used device in metro areas.
- Victoria and New South Wales' threshold for instant loss of licence from speeding is lower than South Australia's. Both states have lower per capita and per VKT road fatality rates than South Australia.

Recommendations

- SAPOL to petition for immediate licence disqualification for motorists caught exceeding the speed limit by ≥30kph in SA.

Conclusion

Fixed and mobile speed cameras make an important contribution to increasing motorist speed-limit compliance, reducing serious injury crashes and saving lives. Speeding fatalities frequently go hand in hand with drink driving, drug driving, not wearing a seatbelt and riding a motorcycle. One third of 2014's fatalities that had excessive speed as a driver error were disqualified or unlicensed drivers. This demographic requires further targeting.

There has been an increase in the proportion of motorists speeding since the 1/9/2012 reduction in lesser speeding fine amounts. This indicates the rise in demerit points for lower level speeding offences is not sufficient incentive to comply with the posted speed limit.

Appendix

2014 fatal crashes that had excessive speed as a driver error

Collision type	Driver demographic	LSA	Driver error 1	Driver error 2	Driver error 3	Driver error 4	Seatbelt worn?
Car hit tree	30 yo male	BALSA	Excessive speed	Due care	Alcohol 0.105	Drugs - THC	N
Car hit tree	28 yo male	HFLSA	Excessive speed	Alcohol 0.101	Drugs – THC & meth	-	Y
Motorcycle hit tree	28 yo male **disqualified driver**	EHLSA	Excessive speed	Alcohol 0.133	Drugs - meth		Helmet worn
Car hit tree	20 yo male	HFLSA	Excessive speed	Alcohol 0.154			Uk
Motorcycle vs Utility	35 yo male	EHLSA	Excessive speed	Disobey traffic lights			Helmet worn
Left road out of control	34 yo **unlicensed** male	BALSA	Dangerous driving	Excessive speed	Alcohol 0.299		N
Left road out of control	28 yo female	MMLSA	Due care	Excessive speed	Alcohol 0.129		Uk
Left road out of control	32 yo **disqualified** male	SRLSA	Alcohol 0.259	Excessive speed	Drugs - THC		Uk
Head on	26 yo **disqualified** male	HFLSA	Change lanes to danger	Excessive speed	Drugs - meth		Y
Left road out of control	57 yo male	MMLSA	Distracted	Excessive speed	Drugs – meth, THC		N
Motorcycle hit parked vehicle	40 yo male	SRLSA	Alcohol 0.201	Excessive speed	Inattention		Helmet worn
Right angle	19 yo male	YMNLSA	Due care	Inattention	Excessive speed	Drugs - THC	Helmet worn

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The impact of airbags, electronic stability control and autonomous emergency braking on Australian light vehicle fatalities: methodology and findings

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Abstract

This paper presents estimates of the current and potential impact of airbags, electronic stability control, and autonomous emergency braking on fatalities in light vehicle crashes. This analysis draws on a number of sources to provide estimates and projections of the proportion of the light vehicle fleet equipped with these technologies. It combines these with estimates of the impact of each technology to provide estimates and projections of the impact on fatalities. It is estimated that frontal airbags have reduced light vehicle fatalities by 13%, side airbags by 4%, and electronic stability control by 6% to 2014. It is also predicted that the impacts of side airbags and electronic stability control will increase significantly as newer vehicles filter through the fleet, and that autonomous emergency braking will begin to lead to significant fatality reductions. Combined, these technologies are predicted to reduce fatalities a further 30% by 2033. This paper draws on the underlying research in BITRE Information Sheet 68 and Report 140 and provides a more in-depth description of the data and research methodology. The paper will be of relevance to those engaged with road safety policy, and to other researchers.

Introduction

From 1990 to 2014, the number of road fatalities in Australia halved (BITRE 2015, BITRE 2014a), and the fatality rate per vehicle kilometre fell by two thirds from 1990 to 2012 (BITRE 2014b). This is attributable to a number of factors, including safer vehicles, safer roads, and improved law enforcement. To some extent there are likely to be offsetting factors, particularly increased driver distraction (BITRE 2010).

BITRE (2010) estimated the impacts of seatbelts, speed cameras, and random breath tests. BITRE (2015) estimated the impacts of two more recent measures: airbags and electronic stability control (ESC). BITRE (2014c) projected the future impacts of airbags and ESC, as well as the future impacts of autonomous emergency braking (AEB), which is now in the early stages of adoption. This paper consolidates the analysis of airbags, ESC, and AEB, and provides more detail on the methodology used for the estimates and projections. Altogether seven specific technologies were analysed: front driver airbags, passenger airbags, side airbags, ESC, ‘basic’ AEB, AEB with vulnerable road user protection, and all-speeds AEB. These are described more fully in the section on background and assumptions.

Methodology

For each technology, the methodology consisted of the following steps:

Adoption in new vehicles:

Firstly, estimates were made of the number of new light vehicles equipped with these technologies each year. These standard feature estimates are based on matching vehicle information from Glass's Research Data (GRD, 2014), which lists specifications and characteristics of vehicles, with new light passenger vehicle sales figures from various VFACTS issues (FCAI, various issues). The number of new light vehicles that include each technology as an optional feature was also estimated.

The method of projecting uptake in new vehicles to 2033 differed for each technology. For airbags and ESC, which are already mandated, it was assumed that all new vehicles will have these technologies. For AEB, future uptake was assumed to follow a logistic diffusion process, similar to that of earlier technologies (see the next section).

Fleet estimates: In order to estimate the impact on fatalities, it is necessary to transform estimates of uptake in new vehicles to estimates of the proportion of the fleet that is equipped with each technology. That is, it is necessary to estimate the rate at which vehicles without each technology are removed from the vehicle fleet. This was done using data from the ABS Motor Vehicle Census (ABS 2014). Fleet-level projections to 2033 were produced using past rates of removal from the fleet.

Fatality reductions for each crash class: Drawing on published estimates, assumptions were made about the likely reductions in fatalities from each technology, for the particular classes of crashes in which the technologies are effective. The studies drawn on, and the assumptions used, are detailed in the next section. Effort was made to ensure that the estimates were as relevant to the Australian context as possible. For example, it was not possible to use estimates of the impact of airbags from the United States, as the implementation of airbags is somewhat different to that in Australia.

Frequency of fatalities by crash class: The frequency of fatalities in light vehicle crashes of each crash type was estimated using data provided to BITRE from jurisdictions. For future years, it was generally assumed that the proportions of light vehicle fatalities in each crash type remain unchanged. The exception was for fatalities in front-impact crashes, which are the class most likely to be reduced by airbags. For this class of crashes, the estimated reduction in fatalities from airbags was taken as a baseline for the analysis of AEB.

Finally, the assumptions about the impact in each crash class were combined with the estimates of the frequency of fatalities in each class, and the share of the light vehicle fleet equipped with the technology, to produce estimates of the fatality reduction in each year. All results presented here are proportional reductions relative to a 'base case' in which the technologies did not exist, rather than in terms of the number of lives saved. In BITRE 2014c it was assumed that fatality rates per vehicle kilometre travelled would remain constant in the absence of these technologies, which is consistent with the impacts of other measures (notably seatbelts) already being fully realised, and other improvements (such as improved infrastructure) being offset by increased driver inattention.

Background and assumptions

This section provides a brief background to each of the technologies analysed, including the Australian context, estimates of the impacts from other literature, and the assumptions used for this analysis. The assumptions are also tabulated in Table 1.

Airbags: Frontal airbags began to be introduced as a standard feature in light vehicles in around 1990, and by 2006 were a standard feature in over 90% of new light vehicles. Passenger airbags were taken up at a slower rate, but were also a standard feature in over 90% of new vehicles by 2007. Frontal airbags are most effective at reducing trauma in front-impact crashes. Paine (2002), drawing on estimates by Langwieder, K., Hummel, T. and Anselm, D. (1998) and MUARC (1992), assumed that driver airbags reduced fatalities by 25% in front-impact crashes, and that passenger airbags reduced fatalities by 20% in frontal crashes in which a passenger was involved. These figures have been assumed in our analysis.

Side airbags began to be introduced as a standard feature in around 1995 (D'Elia, A., Scully, J. and Newstead, S. 2012). By 2014 over 75% of new light vehicles were equipped, and 36% of the light vehicle fleet. Side airbags are most effective at reducing trauma in side-impact crashes, which account for approximately 20% of fatalities in Australia (UN 2013). D'Elia et al (2012), analysing side impact crashes, found that combination airbags were associated with a reduction of 51% in the odds of death and injury to all body regions. In our analysis it was assumed that side airbags reduced fatalities in side-impact crashes by 51%.

ESC: ESC involves an on-board computer detecting when loss of control is imminent then restoring control through reducing power and applying individual braking to each wheel (FCAI 2015). ESC began to be included as a standard feature in vehicles sold in Australia in around 1999, and by 2014 nearly all new light vehicles were equipped with ESC. ESC was mandated for all new passenger cars in 2013 (FCAI 2015) and will be mandated for all new light commercial vehicles in 2017 (DPMC 2013). ESC is most effective at reducing single-vehicle crashes, particularly 'run-off-road' crashes, in which a vehicle leaves the roadway. Single-vehicle crashes accounted for 47% of Australian road fatalities in 2013 (BITRE 2014a) and BITRE estimates that run-off-road crashes accounted for 38% of road fatalities in 2008-2012 (BITRE 2014c). Scully et. al. (2007) cite international findings that fatal single vehicle (car) crashes are reduced by 53% by ESC, and that run-off-road crashes are reduced by 54.5%. Here, we assumed a 53% reduction in fatalities from run-off-road crashes.

Note that airbags reduce the fatality risk in some of the crashes that will be avoided by ESC, meaning that the impact of ESC on fatalities will be slightly lower than it would be in the absence of airbags. This effect has not been taken into account in this analysis, and doing so would require more detail on crash type than is available. Based on the estimated impact of airbags, and the proportion of ESC-equipped vehicles that also have airbags, this could potentially reduce the estimate of the impact of ESC alone by up to 0.7 percentage points in 2014, and 3 percentage points in the 2033 projections.

AEB: AEB systems improve safety in two ways: firstly, they help to avoid accidents by avoiding critical situations early and warning the driver; and secondly they reduce the severity of crashes by lowering the speed of collision and, in some cases, by preparing the vehicle and restraint systems for impact. AEB first started appearing in sales figures as a standard feature in new light passenger vehicles in around 2010. By 2013 AEB was appearing as a standard feature in a number of the premium light passenger models. A large proportion of AEB systems appearing as a standard feature in new light passenger vehicles are the basic AEB system intended to mitigate urban crashes at lower speeds, notably rear-end crashes at intersections in stop-start traffic.

Anderson, Doecke, Mackenzie and Ponte (2013) looked at the potential benefits from AEB from crash reconstructions and simulation and found overall reductions in risk produced by the various AEB systems were predicted to reduce fatal crashes by 20-25 per cent, but noted 'the differences in the way that systems operate will make a material difference to their effectiveness, in terms of either speed reductions or injury risk.'

In order to model the impact of AEB, we made the following assumptions about different subsets of crashes in two different speed contexts (using speed zone as a proxy). Basic AEB systems, with and without vulnerable road user protection, are assumed to be effective in reducing collision crashes and crashes involving pedestrians and pedal cyclists in speed zones of 60 km/hr or less. High speed AEB systems are assumed to be effective in all speed zones (including where the speed zone is unknown) for collision crashes, including pedestrian and pedal cyclist crashes. It was assumed that all levels of AEB reduced relevant subsets of fatal crashes by 20% and injury crashes by 25% (the lower bound of the effectiveness found by Anderson et al (2013)).

The adoption of each of these three AEB technologies in new vehicles was assumed to follow a logistic diffusion process. Basic AEB, without vulnerable road user protection, was assumed to reach 90% of new vehicles by 2022. AEB with vulnerable road user protection was assumed to reach 90% of new vehicles by 2027, and all-speed AEB with vulnerable road user protection was assumed to reach 90% of new vehicles by 2039.

By the time AEB becomes common, many of the fatalities that it would have saved will have already been saved by airbags. This was accounted for in the assumed proportion of fatalities from crashes of those classes.

Findings

This section highlights some of the notable findings. Findings are also tabulated in Table 1, which summarises the assumptions used, the estimated uptake and crash type shares, and the resulting reduction in fatality risk in 2014 and 2033. Figure 1 shows the estimated, and projected, proportions of the light vehicle fleet equipped with each technology from 1990 to 2033. Figure 2 shows the estimated proportional reduction in fatalities from airbags and ESC from 1990 to 2014. Figure 3 shows the fatality rate per safety weighted vehicle kilometre from 1990 to 2014, and includes the predicted contributions of earlier measures considered by BITRE (2010): seatbelts, random breath testing, and speed cameras. ('Safety-weighted' vehicle kilometres account for changes in traffic composition, by converting vehicle kilometres to light vehicle equivalent units. See BITRE (2014) for more detail.)

In total, airbags and ESC, combined with the continuing impacts of random breath testing and speed cameras, can account for much of the observed reduction in the fatality rate since 1990. However, reductions in the fatality rate could also be driven by infrastructure improvements, speed limit reductions, improved enforcement, or other vehicle improvements. The impacts of a range of other potential measures are discussed in BITRE 2014c. As discussed in BITRE 2010, some of these reductions may have been offset by increases in distraction due to mobile devices. While over the long term the actual fatality rate has fallen by roughly the same proportion as predicted by this analysis, in some years it has fallen faster and in others slower.

As of 2014, airbags were found to have had the greatest impact, collectively reducing fatalities by 17%. This is explained by the relatively high proportion of the fleet already equipped with airbags, and the high proportion of crashes that are front-impact. The impact of airbags is expected to double by 2033, as almost all vehicles without airbags are scrapped. (Note that the analysis implicitly attributes some saved fatalities to airbags, which would have also been avoided by AEB). It is notable that despite airbags having been standard in new vehicles for over 20 years, they are still driving a year-on-year reduction in the fatality rate. This is because there are a significant number of light vehicles still not equipped with airbags (around 21% of the fleet), which are gradually being removed from the fleet.

The impact of ESC was estimated to be only around 6% in 2014, due to its more recent uptake in new vehicles, and consequently the large proportion of the fleet without the technology. By 2033, it is expected to be in almost all light vehicles, leading to fatalities 18% lower than otherwise. While the impact of ESC in relevant crashes is higher than for airbags (in part because ideally the crashes are avoided altogether), the number of relevant crashes is lower, as ESC is less useful at avoiding fatalities in frontal collision crashes.

The impact of AEB was insignificant in 2014, and was also estimated to be lower than the other technologies in 2033. This is partly because the technology will take a long time to filter through the vehicle fleet, but also because the assumed impacts per crash are lower. However, due to the early stage of development of AEB compared with the other technologies analysed, the uncertainty surrounding the impacts is greater.

Table 1 Summary of assumptions and estimates

Technology	Relevant crash types	Share of fatalities accounted for by relevant crash types (%)	Fatality reduction, relevant crashes (%)	Fatality reduction, equipped vehicles (%)	Share of LV fleet equipped, 2014 (%)	Total fatality reduction, 2014 (%)	Share of LV fleet equipped, 2033 (%)	Total fatality reduction, 2033 (%)
Driver airbags	Front impact	60[a]	25[a]	15	79	12	99	15
Passenger airbags	Front impact with passenger	12[a]	20[a]	2	55	1	97	2
Side airbags	Side impact	20[b]	51[c]	10	36	4	95	10
ESC	Run-off-road	38[d]	53[e]	20	29	6	94	18
Basic AEB	Low speed collisions	10	20	2	3	0	78	1
AEB protection for vulnerable road users	Low speed collisions involving cyclists and pedestrians	10	20	2	1	0	72	2
High speed AEB	Higher speed collisions (including cyclists and pedestrians)	34	20	7	0	0	52	5

(a) Paine 2002, citing Langwieder et al (1998) and MUARC (1992) (b) United Nations 2013 (c) D'Elia, Scully and Newstead 2012 (d) BITRE unpublished data (e) Scully and Newstead 2007, citing US research

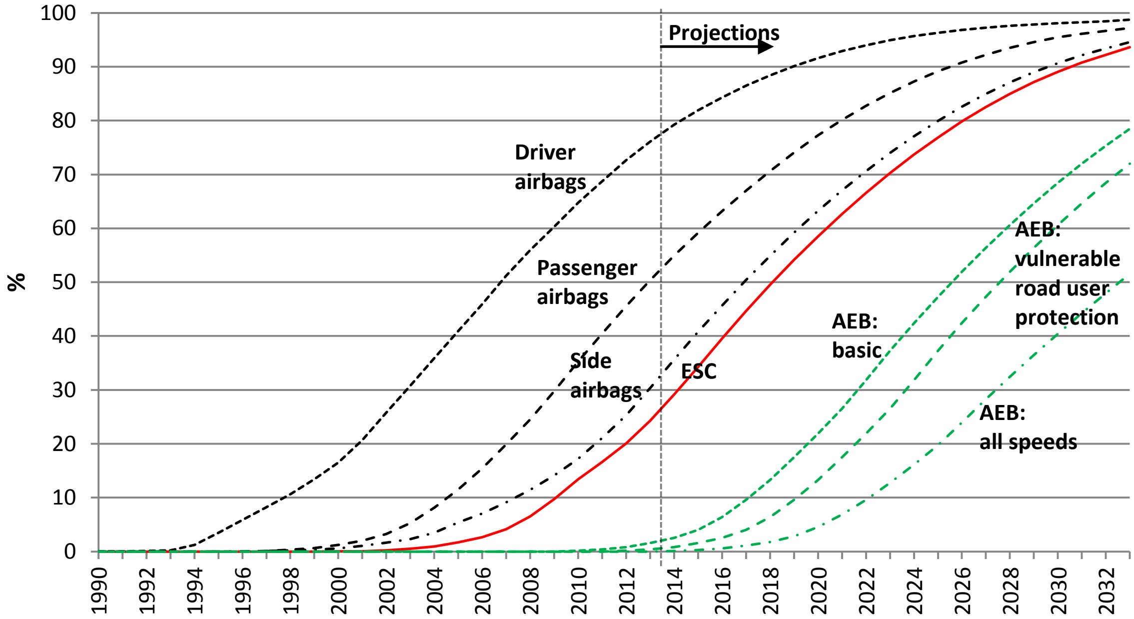

Figure 1 Proportion of light vehicle fleet with airbags and electronic stability control. Source: BITRE estimates derived from VFACTS (various years) Glass's (2014), ABS (2014)

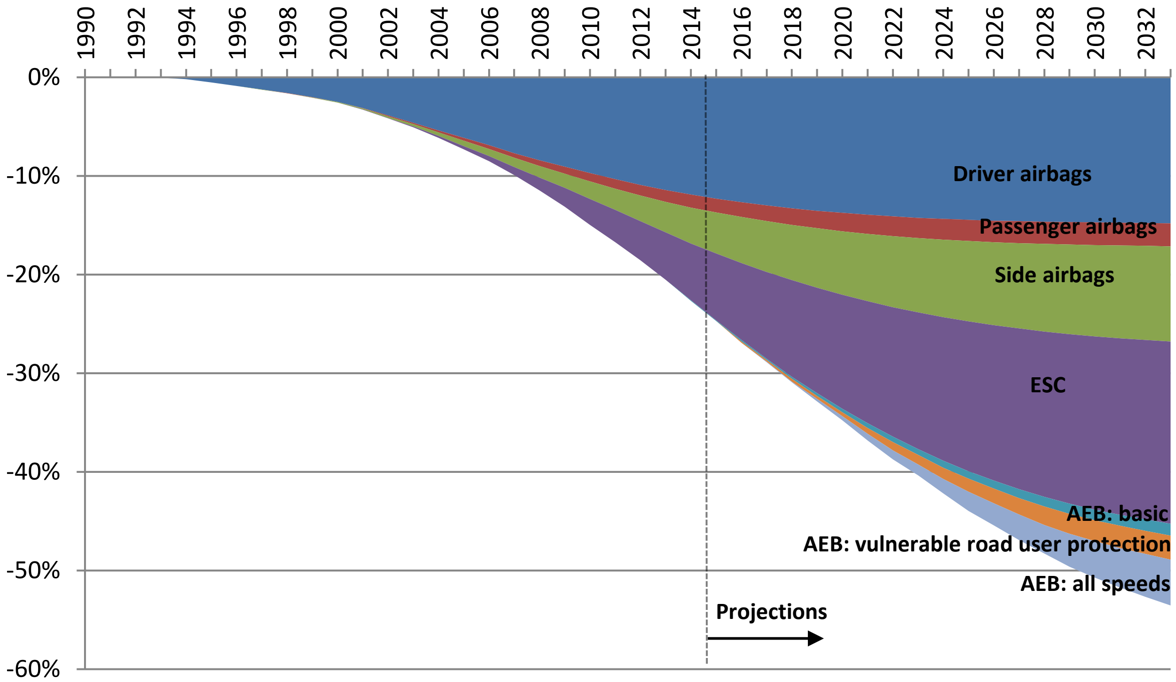

Figure 2 Estimated proportional impacts of selected measures on fatalities. Source: BITRE analysis

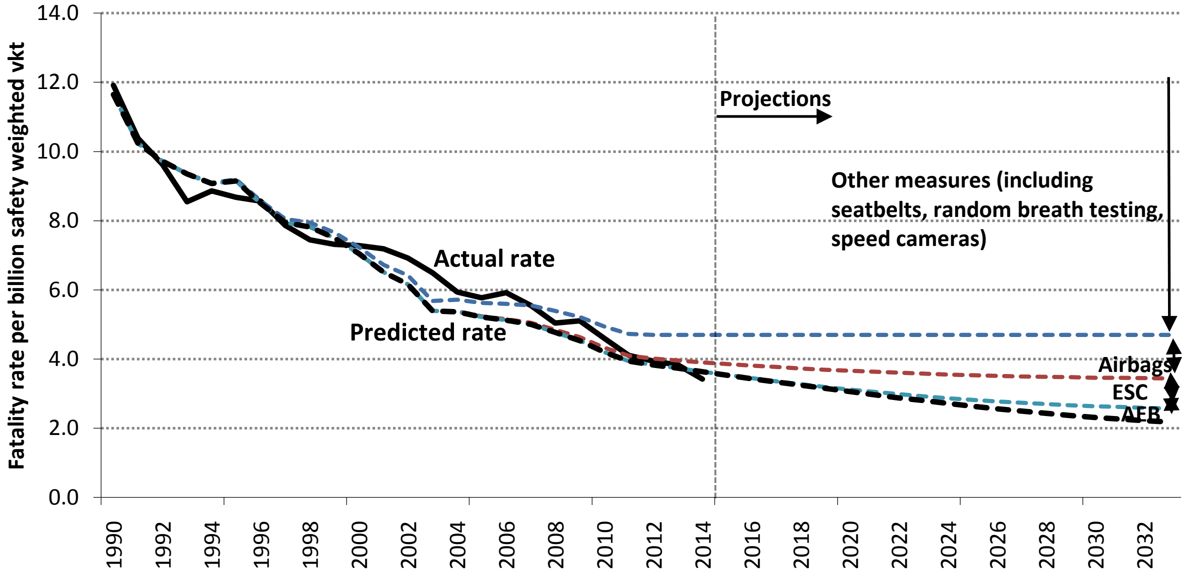

Figure 3 Estimated impacts of measures on fatalities per billion safety weighted vehicle kilometres travelled. Sources: BITRE 2014b, BITRE analysis

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Difficulties in engaging novice disqualified drivers in a longitudinal study into their behaviours and attitudes

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Introduction

In South Australia drivers aged between 16 and 25 who have had their learner's permit or provisional driver licence disqualified are required by law to attend a *ur choice* workshop. This interactive 90 minute workshop, delivered by trained facilitators, addresses the high incidence of road crashes involving young drivers. Participants in small groups (up to 12) discuss the reasons young drivers are involved in crashes, explore how road crashes affect individuals, families and friends and have the opportunity to think about strategies that could make them a safer driver. The majority of workshops are held in the evening with day time sessions occasionally available.

Following a three year (2012-2015) longitudinal survey involving 9318 potential participants, driver behaviour and attitudinal data relating to road safety was eventually gathered from a total of 99 young people who responded to the four questionnaires over a six month period.

The purpose of this paper is to describe the methodological challenges involved when engaging South Australian drivers to participate in the *ur choice* workshop.
The experience gained during the conduct of this study will contribute to the overall body of knowledge relating to processes used to engage this demographic.

Methodology

The data collection process used throughout this study was logistically complex, owing to the desire to follow attitudes of the workshop participants over a 6 month period (i.e. pre-workshop attendance, 1 week, 3 and 6 months post-workshop attendance) and aiming for the completion of 4 survey forms per final respondent. These 4 surveys were undertaken between March 2012 and January 2015 employing online (via customised websites) and paper (posted) questionnaires. A summary of the survey method is illustrated, in Figure 1: Overview of methodology.

Table 1 shows the responses received, by all methods, for each stage of the study:

Table 1: Responses received for each stage of the study

Stage	Number dispatched/invited	Number completed/received	Response rate %
urchoice 1: pre-workshop	9318	1816	19%
urchoice 2:	1594	390	24%

1 week post-workshop			
urchoice 3: 3 months post-workshop	316	148	47%
urchoice 4: 6 months post-workshop	130	99	76%

At each stage data was collected via self-completion paper or online questionnaires/forms posted to individuals' home addresses. Respondents' contact details remained secure, confidential and separate from the research data.

Time: -1 month pre-urchoice workshop

Participant is contacted by DPTI (via mail-out) and invited to attend a urchoice workshop at the specified time/date/location and is also invited to participate in study.

↓

Time: - 2 weeks pre-urchoice workshop

Participant confirms attendance and contact details. Provides permission to be included in study. Prior to attending urchoice workshop, participant's current knowledge and attitudes are **initially** surveyed (5 mins) via mail-out questionnaire or online/website

↓

Time: -1 week pre-urchoice workshop

If participant has not responded, they are contacted (by phone) and permission/survey response is requested.

↓

Time: urchoice workshop attendance

Participant attends urchoice workshop.

↓

Time: + 1 week post-urchoice workshop

Participant is contacted for **second** survey of knowledge and attitudes (5 mins) via mail-out questionnaire/online. Results are reported, together with the pre-seminar responses.

↓

Time: + 3 months post-urchoice workshop

At three months post-urchoice workshop, participant is contacted again for **third** survey of knowledge and attitudes (5 mins) via mail-out/online. Results are reported with the pre- and 1 week post-seminar responses

↓

Time: + 6 months post-urchoice workshop

At 6 months post-urchoice workshop, participant is contacted again for **fourth** survey of knowledge and attitudes (5 mins) via mail-out/online. Results are reported with the total pre- and post-seminar responses.

↓

Time: Project completion

All results and relevant implications are presented/circulated.

Figure 1 : Overview of urchoice study methodology

Discussion

The original, broad objective of the study was to evaluate whether there were any learnings delivered and retained over the longer term, by the *urchoice* workshops.

Upon reflection on the study method the finding of value to the research team and potentially others working in this field, has been the experience of the challenges of conducting a sustained investigation into this particular group. The nature of the actual and potential respondents created significant issues with data confidence and contributed to the high costs of conducting much-needed research among that group.

The original sampling objective for the study was to close the longitudinal evaluation when n=400 *urchoice4* surveys had been received and to run analysis on the data gathered from a robust set of responses. The original study period was estimated to require 12-15 months from the first *urchoice1* (pre-workshop) questionnaire to the final n=400, *urchoice4* response.

The rate of responses to this study were severely underestimated at every step of the way, beginning with an unwittingly optimistic assumption of 50% response rates across the four surveys relating to levels of engagement with each stage.

Table 2: Assumed vs actual response rates

Stage	Number Originally estimated	Number completed/received
urchoice 1: pre-workshop	2400 (assumed 50% response rate)	1816 (achieved 19% response rate)
urchoice 2: 1 week post-workshop	1200 (assumed 50% response rate)	390 (achieved 24% response rate)
urchoice 3: 3 months post-workshop	800 (assumed 50% response rate)	148 (achieved 47% response rate)
urchoice 4: 6 months post-workshop	400 (assumed 50% response rate)	99 (achieved 76% response rate)

Contrary to expectations of achieving n=400 responses, the *urchoice4* study (6 months post-workshop) closed when just 99 respondents had completed their 4th questionnaire. To achieve this final sample it took 3 years, 9318 clients, 753 *urchoice* workshops, an assortment of additional competition draws, retail vouchers and literally hundreds of hours and thousands of telephone calls and SMS reminders to achieve that reduced and modified result.

It was apparent from the outset that many of these young, disqualified drivers (as they were pre-workshop, when first invited to participate) were exceedingly reluctant to complete questions, cooperate with "the government" and/or participate in any data-gathering endeavour without the promise of significant personal gain.

In convincing respondents to initially become involved, and then sustain their involvement, the research team employed a number of tactics, including:

- Mentioning the surveys/study at all workshops
- Mentioning the surveys/study during telephone enquiries relating to workshops and licences
- Providing links to the surveys on the *urchoice* web page

- Multiple call-backs from Gen Y staff, requesting/reminding people to complete the survey
- Competition draws for $50, $100, $200 retail vouchers (e.g. iTunes, Coles Myer, BigW etc.)
- Competition for an iPad
- Appeals to a sense of community and improvement to driver safety for all road users
- Promises of $10 and $20 vouchers for study participation (i.e. not a chance draw).

Nevertheless, the process was very slow, frustrating and expensive and the decision to close off the study at the end of January 2015 was taken with the certainty that, at the rates of response being achieved, it would take an impractical length of time and resourcing to achieve the original target of the n=400 sample.

While the research team were confident of the veracity of the data received from the final ur choice4 (and earlier respondents, who dropped out at stages *urchoice2* and *urchoice3*), statistical significance was unable to be achieved and there ~~is~~ remains concern that these responses were gathered from the more compliant members of this survey population, namely those who *did* want to assist and be involved in the study. Those who did not want to be involved were likely to be the less cooperative members of this population and may have demonstrated different attitudes and behaviours to those contributing to the *urchoice* data. In retrospect, it is unfortunate that the research team has no way of measuring the effect of this self-selecting sampling methodology.

Conclusions

While the study sought to engage a range of 16-25 year old disqualified drivers to evaluate the effect of the *urchoice* workshop intervention, the issues with achieving engagement from this highly reluctant survey population threw many challenges in gathering and acting upon the data received.

It is recommended that any future research among this disqualified novice driver group takes these challenges into extra account when planning and resourcing studies of significance to road safety.

Abrasion resistance of motorcycle protective clothing worn by Australian motorcyclists

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Introduction

Motorcycle crashes represent a significant health burden to the community, accounting for 22% of serious casualties on Australian roads each year. In addition, it is well known and accepted that motorcyclists are significantly overrepresented in crashes given that motorcycle usage accounts for only one percent of vehicle kilometres travelled (ATC, 2011; BITRE, 2009).

Soft tissue injuries are the most common injuries experienced by crashed motorcyclists (NSAI, 1998, 2003, 2010). Protective clothing has been developed to help prevent these injuries, yet the performance of protective clothing in Australia is still variable (de Rome et al., 2011). In Australia, while there are no design standards for motorcycle protective clothing, there are non-mandatory Australian Guidelines for manufacturing. However, the guidelines specify the use of an abrasion testing machine which is not designed for the purpose of testing motorcycle protective clothing. Therefore, at present in Australia, there are no mechanisms in place to help maintain a high quality of performance.

There is a European Standard for motorcycle protective clothing and this Standard specifies the general requirements for clothing intended to protect the rider against mechanical injury. This Standard (EN13595) was developed from work undertaken by Woods who examined crash damage to 100 motorcycle suits (99 leather and 1 Kevlar) and observed where damage most frequently occurred as well as the type of damage. Based on the damage distribution, a clothing template was developed that specified four zones, each with different levels of protection dependent upon the clothing's ability to resist the main types of damage: burst, cut, abrasion and tear. (Woods, 1996a, 1996b).

It is still unknown how well the performance of materials in the laboratory tests of EN13595 relates to the performance of clothing in real world motorcycle crashes. With a larger variety of fabrics currently available to motorcycle riders, the performance of clothing in the real world may have varied since Woods developed the Cambridge Abrasion machine in 1996. There is a need to validate the observations on which the EU Standard requirements are based, particularly using a greater range of materials and more modern materials. Additionally, there has been no study since the work of Woods (Woods, 1996b) that examines the adequacy of the test methods. The objective of this study was to address this gap and, as abrasion resistance is considered to be the highest priority compared to other damage types (Meredith, Brown, Ivers, & de Rome, 2013), this study set out to determine whether the approach taken to assess abrasion resistance in the EU Standard is appropriate. Specifically, the aim of this study was to examine the relationship between the abrasion resistance performance of the clothing worn by the motorcycle riders when tested as required in EN13595 and the probability of real world injury outcome.

Method

To address the study aims, the study examined the abrasion resistance of clothing obtained from crash-involved riders and then compared this to the riders' injury outcomes.

Sample.

Data was collected during in-depth crash investigation. Motorcycle riders who had been involved in motorcycle crashes were recruited from three Sydney hospitals and one regional hospital from August 2012 to August 2014. Riders had to be at least 16 years of age. Following recruitment, riders completed a face-to-face interview and hospital medical records were reviewed. The crash scene and motorcycle ridden were also inspected. Where possible, clothing was inspected and collected from riders for testing. Clothing was sometimes unable to be inspected or collected due to the clothing having been thrown out, sent to insurance companies or lack of rider consent. If the clothing was inspected and photographed but the rider did not consent for the clothing to be kept and tested, the brand name and model of the clothing was recorded and new clothing items were purchased to the same specification.

Test methodology.

The testing apparatus and methods were based on the test procedures outlined in EN13595. However, as the test equipment used at NeuRA is known to abrade materials more slowly than equipment used in EN13595 compliance testing, a scaling factor, developed from validation tests using this reference material was applied to all measured times.

In summary, circular samples of each material in the garment were retrieved from the garment. Samples were taken from locations where there was no crash damage. Samples were then attached to the sample holder using a hose clamp. Fibres were oriented either along the warp, weft or at 45 degrees to the warp and weft so that there were two samples tested at each fibre direction. Once the sample was prepared, the motor was then switched on and the abrasive belt brought up to the appropriate speed (8m/s). The sample holder with the fabric sample attached was then dropped onto the moving belt and the time taken for the fabric to abrade through was measured. As specified in the Standard procedure, after every 10 tests, a reference fabric was tested to adjust the abrasion time to account for wear of the abrasive belt during testing.

Analysis.

Data collected using the above procedure including the scaled time to hole measures was used to examine the relationship between the abrasion resistance performance of the clothing worn by the motorcycle riders. Each garment was classified by whether it was within the Level 1 abrasion resistant time requirements (yes/no), and for each material in each garment, an abrasion time was assigned. Binary logistic regression was performed to examine associations between abrasion time and occurrence of soft tissue injuries (excluding contusions) using general estimating equations to account for repeated measures. Materials which had not suffered an impact during the crash (no soft tissue injury or damage to the material) were excluded from the analysis. An injury risk curve was then developed. Development of the injury risk curves followed the recommended procedure outlined in ISO 18506 (International Organization for Standardization, 2014)

Results

Riders were commonly wearing jackets designed for motorcycle use (70.7%) and gloves designed for motorcycle use (64.1%), but were not as likely to be wearing footwear (38%) or pants designed for motorcycle use (35.9%). Gloves were the most frequently EU Standard certified clothing item, but represented only 6.5% of gloves worn. Only three percent of upper garments and one percent of lower garments were certified. Leather was the most common material used in footwear (63%), jackets (41.3%) and gloves (62.5%), while pants were most frequently made from medium weight materials (52.2%).

There were a total number of 633 damage locations identified during inspections or as noted by the participants. On average, upper garments had three specific locations of damage, while the lower garments, gloves and footwear had on average two points of damage. Abrasion damage was the most common type of damage (77.3%), and this remained consistent in all of the garment types. Tears were also relatively frequent (11.4%), but there was little evidence of burst (3.6%) or cut damage (1.3%). Extensive damage, where there was complete failure of the material so that the rider's skin became exposed, occurred in 117 of the 633 damage locations (18.5%). This consisted of 41 (16.1%) of cases of damage to upper garments, 56 (36.6%) cases of damage to lower garments, 16 (11.7%) cases of damage to gloves and 6 (4.4%) cases of damage to footwear.

Table 1 displays the number of garments found to have abrasion resistance within the Level 1 time requirements of the EU Standard using the scaled time to hole measures. For both upper and lower garments, the majority of the clothing worn by the riders in this study did not meet this requirement. There was one upper garment that was not designed for motorcycle use which was within the requirements of the Standard.

Table 1. Number of clothing items which were within the Level 1 time requirements specified in EN13595

Type of garment	Clothing item	Within time n(%)	Not within time n(%)
Designed for motorcycle use	Upper garment	5 (23.8)	21 (76.2)
	Lower garment	4 (36.4)	11 (63.6)
Not designed for motorcycle use	Upper garment	1 (7.7)	13 (92.3)
	Lower garment	0 (0)	47 (100)

The average time for the garments to abrade is shown in Table 2. Lower garments (0.98 sec) had a typically faster abrasion time than upper garments (1.25 sec).

Table 2. Average abrasion time for the different clothing items

Clothing item	Abrasion time (sec)	
	Mean (sd)	Range
Upper garment	1.25 (1.80)	0.02-8.96
Lower garment	0.98 (2.70)	0.02-20.36

The results of the binary logistic regression examining the association between the abrasion time of all materials and the occurrence of soft tissue injuries, is shown in Table 3. The dfbeta statistic was examined to determine if there were any values which should not be included in the analysis and no outliers were found. The results suggest that with an increase in abrasion time, the odds of a rider not being injured increased significantly (OR = 1.285, 95% CI: 1.035-1.595).

Table 3. Association between soft tissue injury and length of time taken for the clothing to abrade

Outcome variable	Explanatory variable	Odds ratio	p-value	95% CI
Rider uninjured	Abrasion time (s)	1.285	0.023	1.035-1.595

Discussion

This research has demonstrated that the probability of a rider *not* suffering a soft tissue injury increases significantly as the time taken for the clothing to abrade increases. This suggests there is significant benefit in increasing the time taken to abrade. It also indicates that the Cambridge Abrasion machine ranks clothing effectively in terms of the ability of the clothing to protect from soft tissue injuries in real world motorcycle crashes, even when modern materials are part of the sample. This means it may be an appropriate method to adopt for testing motorcycle clothing in Australia.

The majority of clothing worn by riders in this sample that was designed for motorcycle use did not fall even within the Level 1 abrasion resistance requirements of the Standard based on the results from this machine. This indicates a need to improve the quality of clothing sold to Australian motorcyclists and supports the need to adopt some form of quality control or consumer information program to help improve the quality of clothing worn by Australian riders, or at the very least allow riders to make informed decisions about the clothing they wear.

The main limitation of this research is that the absolute time to hole is generated using a scaling factor which has not yet been validated. This means the results presented in Table 3 may be overestimating the proportion of clothing that was within the requirements of the Level 1 criteria within EN 13595. All materials are currently being re-tested on equipment at Deakin University to confirm the preliminary results presented here, and to validate the scaling factor used. The results presented here should be viewed as preliminary. Another limitation is the relatively small sample size which prevents examination of the performances of the different materials.

Conclusion

This preliminary work found a significant association between likelihood of soft tissue injury and abrasion time, suggesting the Cambridge impact abrasion resistance test method is an appropriate method.

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Evidence that truck driver remuneration is linked to safety outcomes: a review of the literature

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Abstract

The evidence that remuneration and pay systems have an effect on truck driver safety is growing. A review of the scientific literature shows the connections between remuneration and safety risk factors and outcomes. A study conducted in one large American trucking company found that where drivers are paid mileage rates, a 10 cent increase in the rate paid per mile results in a 1.76% reduction in the risk of crashing. Not only do pay rates make a difference in safety outcomes, but also the way in which drivers are remunerated influences the likelihood of unsafe behaviours and crashes. A number of studies conducted between 1990 and 2014 in Australia, the United States (US) and Europe, focused on the safety effects of truck driver payment methods. There is also evidence that trucking industry economic pressures play a role in safety performance. This paper summarises the findings of the research on this topic.

Introduction

There has been an abundance of research into safety risk factors that attempt to explain fatal truck crashes. For example, it is well established that driver fatigue (Crum & Morrow, 2002; Feyer & Williamson, 1995; Feyer, Williamson, Friswell, & Sadural, 2002; Hanowski, Hickman, Olsen, & Bocanegra, 2009) is a prevalent factors in these crashes. In a major US study into truck crash causation, a number of “critical reasons” for these crashes were identified (Department of Transportation U.S., 2006). Vehicle factors, especially concerning brakes and tyres were 10% of the critical reasons. Driver behavioural factors were the most prominent, especially driving whilst drug affected or fatigued and driving too fast for conditions. Knowing about prevalent crash risk factors enables authorities to focus regulatory interventions to the most important behaviours to control, as well as to guide and educate companies on things they should be doing to reduce crash risks. Much of the road safety regulation is focussed on controlling driver behaviour.

Some studies have gone a step further to determine some of the underlying conditions in which these risk factors manifest. Richards (2004) found that fatigue, peer pressure, wanting to fit the trucking ‘image’, socialisation, relaxation and addiction were powerful motivations for truck drivers to use drugs. Also, Kemp et al (2013) found that time pressures can lead to physical fatigue and emotional exhaustion, which in turn lead to negative attitudes about compliance with hours of service regulations.

Why do drivers feel excessively time-pressured? Perhaps there is something inherent in the characteristics of the trucking industry that perpetuate the manifestation of things like time-pressures. Michael Belzer (2000), citing that practices of paying drivers low piece meal pay rates for driving described the trucking industry as “sweatshops on wheels”. A literature review by Johansson et al (Johansson, Rask, & Stenberg, 2010) found that 27 out of the 31 studies examined indicated a link between piece meal pay methods and adverse health and safety outcomes.

A literature review focused on evidence of effective safety management characteristics (Mooren, Grzebieta, Williamson, Olivier, & Friswell, 2014) found that driver pay rates and company profitability have a bearing on safety outcomes. There are essentially two types of payment methods for drivers of heavy transport vehicles. Companies can choose to pay drivers by the hour or with a wage or salary that covers all work undertaken by drivers, including driving tasks as well as time spent loading or unloading the truck and/or queuing or waiting to be loaded or unloaded. The alternative method is termed “productivity payment.” This is a compensation method that ties financial compensation to output, either by truckloads delivered, kilometres driven, or profits earned by a job. Under this type of payment method, the employer may or may not pay for time spent on non-driving activities such as loading, unloading or queuing/waiting. Sometimes either a flat fee is given to the driver for some or all of these tasks. Sometimes payment for time the driver spent waiting is conditional on how long the driver spends waiting, e.g. drivers get paid for time after the first hour. The two methods can be combined in other ways as well, such as drivers on hourly pay may receive bonuses as a share of the profits earned by a company.

This paper specifically reviews the growing literature on the connections between driver and company compensation and safety. The aim of this study was to identify whether truck driver pay and pay systems influence safety risk, whether driver remuneration, and whether trucking company profitability has a bearing on safety outcomes. In addition, the paper sought to identify features of the trucking industry that provide the conditions that influence poor safety performance.

Method

The authors had conducted a prior literature review examining original research papers on safety management systems (2014). This review found a number of studies suggesting that an important safety management characteristic for heavy vehicle operators was the way in which drivers were remunerated for their work (Monaco & Williams, 2000; Williamson, 2007) and driver pay rates (Belzer, Rodriguez, & Sedo, 2002; Rodriguez, Targa, & Belzer, 2006). Related to these issues, a number of studies in this review found links between company financial performance, efficiency, unionisation and size (Britto, Corsi, & Grimm, 2010; Bruning, 1989; Corsi, Grimm, Cantor, & Sienicki, 2012; Fernandez-Muniz, Montes-Peon, & Vazquez-Ordas, 2009; Knipling & Bergoffen, 2011; Mayhew & Quinlan, 2006) also influenced safety outcomes. Initially, the references listed in the studies first examined were obtained as well as studies that cited these publications were obtained. A Google Scholar search on the terms, truck driver pay and safety risk, driver remuneration, trucking company profitability and safety found 16,500 references relating to these topics. Then the search was narrowed to include only articles that contained the phrase “driver pay”. This reduced the list to 71 references. A review of titles to exclude light vehicle studies, and those that did not directly link financial reward and safety outcomes was done. In addition, only studies using original data were included. This process resulted in 29 papers, representing 26 studies, being selected for inclusion in this review of the research evidence connecting pay with safety in the trucking industry.

Results

There are four groups of literature that highlight the connections between safety and remuneration in the trucking industry. These cover: the effects of driver payment methods on risk behaviour; the effects of payment levels on safety outcomes; the effects of company financial performance and industrial relations on safety outcomes; and the effects of industry financial pressure on safety outcomes. Taking each of these topics in turn an analysis of the evidence of the connection between financial reward and safety is discussed.

Driver Payment Methods and Driving Behaviour

Not only do pay rates make a difference in safety outcomes, but also the way in which drivers are remunerated influences the likelihood of unsafe behaviours and crashes. Studies conducted between 1990 and 2014 in Australia and in the United States (US), which focused on the safety effects of truck driver payment methods are summarised in Table 1.

Table 1. Effects of Driver Payment Methods on Risk Behaviour and Safety Outcomes

Study focus	Author, year	Method/sample	Findings
Effects of driver pay system on propensity to speed, self-impose tight schedules, take stimulant drugs	(Golob & Hensher, 1994)	Cross-sectional survey/ n = 402 Australian truck drivers	Drivers try to optimise money earned by self-imposed time pressure, leading to use of stimulants, leading to speeding (79% are paid based on productivity)
Effects of driver pay method on propensity to speed	(Hensher & Battellino, 1990)	Cross-sectional (pilot) survey/ n = 46 Australian truck drivers	Non-drug users drive 20 km/h slower than drug users Drivers paid on a percentage of truck earnings drive 15 km/h faster
Effects of productivity based payment on driver fatigue	(Williamson, Feyer, Friswell, & Saduri, 2001)	Cross-sectional survey/ n = 1,007 Australian long haul truck drivers	Drivers paid by amount of work done report fatigue more often than drivers paid by the amount of time they worked.
Effects of compensation on driver fatigue risk	(Arboleda, Morrow, Crum, Shelley, & Mack, 2003)	Cross-sectional survey of drivers, dispatchers and safety directors in 116 US trucking companies	Unregulated hours of work and unpaid non-driving work provides incentives for drivers to work longer hours and risk driver fatigue.
Effects of payment methods on drug use	(Williamson, 2007)	Re-analysis of 2 Australian surveys 7 years apart/ n=970 & n=1007	Drivers paid by productivity were 2-3 times more likely to use stimulant drugs.
Effects of payment methods on driver fatigue	(Thompson & Stevenson, 2014)	Cross-sectional survey/ n = 346 Australian truck drivers	Performance based pay encourages drivers to keep driving at the expense of sleep and rest, maintenance and safety checks.
Effects of payment methods on truck insurance claim rates	(Mooren, Williamson, et al., 2014)	Cross-sectional survey/ n=50 Australian heavy vehicle operating companies	• Higher claimers were 4 times more likely to pay employee drivers by truckload or trip

Seven studies[1] in 2 countries from the 1990s to 2014 provide evidence that pay methods affect drivers':

- self-imposed time pressure;
- use of stimulant drugs;
- speeding;
- fatigue;
- truck maintenance and safety checks; and
- insurance claim rates.

[1] Cross sectional survey methods were used.

Productivity-based pay is found to produce incentives to self-impose time pressure, take stimulants, speed and work excessive hours. Productivity pay also predicts driver fatigue and encourages drivers to risk fatigue, poorly maintain trucks and skip safety checks. At a company level, those that pay on the basis of productivity have higher truck insurance claim rates compared with those that pay drivers for all hours worked.

In a survey of 573 US motor carrier drivers in 1997, Monaco and Williams (2000) found that hourly payment for drivers had a 10.2% lower crash risk compared with productivity pay, i.e. when drivers are paid by the mile or as percentage of revenue earned by the company. Moreover, where drivers are paid mileage rates, a 10 cent increase in the rate results in a 1.76% reduction in the risk of crashing.

Effects of driver pay levels on safety outcomes

Eight papers reporting the results of six studies demonstrated links between pay levels and safety. Table 2 presents evidence of the effects of driver pay levels on safety outcomes.

Table 2. Effects of Driver Pay Levels on Safety Outcomes

Study focus	Author, year	Method/sample	Findings
Effects of driver pay on driver turnover and health	(Backman & Järvinen, 1983)	Cohort study/ n = 472 drivers in Finnish Transport Workers Union	Reasons for leaving job: 31% unsatisfactory salary 20% work too heavy 14% irregular hours 12% health affected
Effects of driver pay on propensity to speed	(Hensher & Battellino, 1990)	Cross-sectional (pilot) survey/ n = 46 Australian truck drivers	Non-drug users drive 20 km/h slower than drug users Drivers paid on a percentage of truck earnings drive 15 km/h faster
Effects of driver pay on propensity to speed, self-impose tight schedules, take stimulant drugs	(Hensher, Battellino, Gee, & Daniels, 1991)	Cross-sectional survey/ n = 820 Australian truck drivers	Freight rates for owner drivers influence speed Uncertainty of income encourages self-imposed schedules and drug use
Effects of driver pay on violations of work hours		Cross-sectional survey/n = 1,249 US truck drivers	Low pay and tight schedules predict violations of work hour limits
Effects of driver pay increases on crash involvement	(Belzer et al., 2002) (Rodríguez, Rocha, Khattak, & Belzer, 2003) (Rodriguez et al., 2006)	Cohort study/ n = 11,540 drivers employed by J.B. Hunt (US)	A 10% increase in pay reduced crash risk by 21% A 10% increase in paid days off reduced crash risk by 7%. For every additional cent per mile paid to a driver, the crash count decreases by 8%. A 1% increase in pay corresponds to a 1.33% reduction[2] in crash risk probability.
Effects of payment	(Williamson &	Cross-sectional	Incentive based payment and

[2] The safety benefit of increased pay levels does not reduce over time, but the effect reduces incrementally as rates of pay become higher.

Study focus	Author, year	Method/sample	Findings
methods on driver fatigue	Friswell, 2013)	survey/ n = 475 Australian truck drivers	unpaid waiting times predict driver fatigue.

Six studies[3] carried out in 3 countries from the 1980s to 2014 provide evidence that pay levels affect:

- driver turnover;
- speeding;
- self-imposed schedules;
- stimulant drug use;
- violations of work hour limits; and
- driver fatigue.

One large cohort study (Belzer et al, 2002) found increases in pay reduce crash risks. Moreover, one study (Williamson and Friswell, 2013) found that unpaid waiting time and incentive based pay predicts driver fatigue.

In the early 1980s Scandinavian researchers found strong links between driver pay and driver turnover (Backman & Järvinen, 1983). The most common reasons that drivers gave for changing their work were: unsatisfactory salary (31%), heaviness of the work (20%, irregularity of working hours (14%) and health (12%).

A survey of 820 Australian truck drivers, carried out in 1990, concluded that economic rewards were a major influence on drivers to speed on delivery journeys (Hensher et al., 1991). Work practices of truck drivers, including speeding, self-imposing tight schedules and taking stimulant drugs are encouraged by uncertainty or insufficient earnings. These findings were later again replicated in two additional cross-sectional surveys of Australian truck drivers, in 1991 (n = 970) and in 1998 (n = 1,007) confirming the influence of productivity payment systems on the use of stimulant drug use by drivers (Williamson, 2007). Golob and Hensher (1994), still concerned that a lack of appreciation of the relationship between trucking industry characteristics and on-road safety performance may lead to inappropriate and ineffective regulatory responses, examined the constellation of endemic pressures on drivers to speed on delivery journeys (n = 402 Australian truck drivers). They concluded that rates of financial rewards influences drivers' propensity to speed, self-impose schedules and take stay-awake pills. They also observed a complex relationship of decisions by drivers to optimise financial gains through a series of influences to impose difficult timeframes on themselves, which in turn encourages the use of stimulant drugs, which in turn leads to speeding. The majority of drivers (79%) were paid directly in relation to the earnings of the truck.

In parallel, major surveys of US truck drivers found links between driver pay and safety performance. Braver et al (1992) found that 73% of drivers report that they violate hours of service restrictions and that low pay rates and tight delivery schedules were a major impetus to this violation. Moreover, Belzer et al (2002) concluded that drivers who are paid a higher rate have significantly fewer crashes after estimating from the data that a 10% increase in driver pay from \$0.295 per mile to \$0.324 per mile reduced the probability of a crash by 21% from a 13.8% chance to a 10.86% chance.

Finally, the Williamson and Friswell (2013) survey found that nearly 90% of Australian truck drivers have to wait to load or unload their trucks, but just one quarter of them are paid to wait. Moreover nearly half of these drivers reported that work interferes with family responsibilities.

Industry pressures behind unsafe pay and payment systems

[3] Cross sectional survey methods were used.

Characteristics of the trucking industry itself may in fact make it more dangerous to work in. While road transport of goods is vital to any economy, the industry conditions in the US and in Australia are plagued by fierce financial pressures.

Intense competition in any industry results in lower prices. While this may be seen by consumers as a good thing, when rates paid for the transport of goods by trucks fall below what a company or driver needs to survive, it becomes a safety issue.

In 1935, the US Congress passed an Act that established the authority of the Interstate Commerce Commission to determine safe rates for trucking. However, in 1977 this authority began to be dismantled. Then, Congress formally deregulated the industry by passing the Motor Carrier Act of 1980 (Belzer, 2000).

The Australian Government passed the Road Safety Remuneration Act in 2012. This Act gave powers to a new Tribunal established to determine safe rates for the Australian trucking industry [4]. This Tribunal can make remuneration orders, assist with collective bargaining agreements, resolve disputes and conduct research into pay, conditions and other matters related to trucking safety and remuneration. As this is a relatively new arrangement in Australia, it is too early to assess the effects of this regulation. However, Belzer and others have researched the effects of deregulation in the US.

Table 3 summarises the evidence of the effects of industry pressures on safety outcomes in the US and in Australia.

Table 3 – Effects of Industry Financial Pressure on Safety Outcomes

Study focus	Author, year	Method, sample	Findings
Effects of deregulation on working conditions and safety of truck drivers	(Belzer, 2000)	Analysis of implications on truck driver safety and working conditions after deregulation	Truck driver earnings dropped by 30% between 1977 and 1995. Median weekly hours worked by US truck drivers is 65 and climbs to 95 hours per week at the 90th percentile
Effects of precarious employment on OHS	(Quinlan, Mayhew, & Bohle, 2001)	Review of studies/ n = 92 studies	76 out of 92 studies found precarious employment detrimental to OHS
Effects of commercial or industrial practices on safety	(Quinlan, 2001)	Inquiry/ n = ~50 written and ~60 oral submissions	Low freight rates encouraged pushing the safety margins, influenced by intense competitive pressures, poor business practices, non-compliance to regulations may deliver an economic advantage, performance based payment systems, low job security.
Effects of deregulation, de-unionisation, technology and human capital	(Belman & Monaco, 2001)	Time series population data analysis & cross-sectional survey/ n = 573 US truck drivers	Deregulation of driver wages coincided with a reduction in driver union membership and a fall in driver wages.
Effects of deregulation on workplace injuries	(Savage, 2004)	Time series injury data analysis US 1973-2001	A relationship could not be found between deregulation and truck driver injury rates.

[4] For more information about this go to: http://www.rsrt.gov.au

Study focus	Author, year	Method, sample	Findings
Effects of competitive industry economic pressures on contingent work arrangements and impacts on safety outcomes	(Mayhew & Quinlan, 2006)	Cross-sectional survey/ n = 300 long haul Australian truck drivers	Owner-drivers have worse OHS outcomes than employee drivers and contingent work arrangements increase with competitive pressures in the supply chain.
Effects of non-regulation of remuneration on truck driver safety	(Quinlan & Wright, 2008)	Inquiry/ n = 24 written and 48 oral submissions (consultations)	Regulation, in the context of the chain of responsibility, is needed to ensure that rates of pay and other elements of remuneration in the long haul transport industry may be determined to provide for safe rates, conditions and remuneration.

Australian studies in the early 2000s found that intense competition, poor business practices and non-compliance to regulations led to low freight rates and poor safety. A major inquiry into safety in the Australian trucking industry took submissions from a large number of industry experts and researchers that consistently advised that intense competition, industry tendering practices, low freight rates and pressure from clients was probably the most fundamental source of dangerous practices in the industry (Quinlan, 2001). Part of the Inquiry entailed a survey of drivers (n = 300). The results indicated that there is a percentage and range of physical and psychological health afflictions as well as low-level occupational violence that are disproportionately reported by truck drivers with more prevalence and severity, affecting owner-drivers. There was persuasive evidence in the Inquiry that many operators were not financially viable; and in fact the commercial environment for the industry was such that questioned the financial viability of the industry as a whole. Downward pressures on freight rates meant that the rates were so low as to pressure drivers and companies to *push the margins* (less truck maintenance, more trips, longer hours, speeding, etc.) In summary, it was found that commercial and industrial practices endemic in the Australian transport industry played “an important and significant role in fomenting hazardous practices.” Moreover, the existing mix of transport and occupational safety regulatory authorities and legislative frameworks were found to be less than effective in enforcing safety regulations in this industry. The Inquiry concluded that coordination and resourcing of regulatory activities in relation to safety in the long distance trucking industry are major issues that should be addressed as a matter of urgency.

While Belzer and others have argued that deregulation of the American trucking industry has had a detrimental effect on safety, others have argued that deregulation has improved the industry as it has resulted in contractual relationships between shippers and carriers that make responsibilities more transparent. On the other hand, Crum and Allen (1997) admit that smaller carriers are suffering worsening contractual disadvantages.

Moreover Quinlan, Mayhew and Bohle (2001) also examined the precarious nature of employment in the trucking industry and found that this was detrimental to drivers’ occupational health and safety. Furthermore, owner-drivers – who make up the majority of Australian trucking companies - were found to have worse OHS outcomes than employee drivers. And while non-employing Australian road freight operators make up 60% of the industry, they account for only 11% of the income earned in the industry (ACIL_Tasman, 2003)

Also, US studies found that deregulation of working conditions and remuneration resulted in sharp drops in driver earnings and sharp rises in hours they worked per week and a reduction in union membership and associated fall in driver wages. Belman and Monaco (2001) observed that industrial deregulation in the US resulted in a reduction in driver union membership and a sharp decline in truck driver earnings between 1973 and 1995 (relative to other workers) falling by 21%

exacerbating the wage inequality and increased financial pressure on drivers. In addition, non-unionised drivers were found to earn 21% less than union members. Monaco and WiIliams later found that union employee drivers were 20% less likely to receive a moving violation than non-union drivers. However, an examination of rates of injury in the trucking industry following deregulation of employment conditions did not find a relationship between them, although the researchers have recognized that they could not discount other industry developments that may have mediated the effects of deregulation, such as improved trucks and seat belt usage by drivers (Savage, 2004).

Company financial pressures and relationship to safety outcomes

An analysis at company level, there appear to be relationships between financial performance and safety, between safety management and financial performance and between unionisation and safety outcomes.

Table 4 summarises the literature on the effects of company level financial performance and unionisation of truck drivers and effects on safety outcomes.

Table 4 – Effects of Company Financial Performance and Unionisation on Safety Outcomes

Study focus	Author, year	Method/sample	Findings
Effects of job tenure and profitability	(Bruning, 1989)	Crash data analysis/ n = 468 US trucking firms	Job tenure and firm profitability is inversely related to crash rates.
Effects of safety management on financial and safety performance	(Fernandez-Muniz et al., 2009)	Cross-sectional survey/ n = 455 Spanish trucking firms	Safety management has a positive influence on safety outcomes, competitiveness and financial performance.
Effects of firm profitability on crashes and Government safety ratings for drivers and vehicles	(Britto et al., 2010)	Crash data analysis/ n = 657 US trucking companies	Poorer financial performance in the year prior is associated with more crash likelihood and worse driver and vehicle safety rating scores
Effects of firm size and contingent employment on OHS outcomes	(Mayhew & Quinlan, 2006)	Cross-sectional survey/ n = 300 Australian long haul drivers	Owner-drivers are most likely to experience ill health, stress, chronic injury and crashes compared with small and large company drivers
Effects of efficiency management practices on safety	(Knipling & Bergoffen, 2011)	Cross-sectional survey/ n = 132 US safety managers, 89 safety experts & 11 company interviews	Trip and route planning, use of maintenance management software, reducing empty trips, providing navigational and monitoring systems, reducing loading/unloading delays & using speed limiters have a positive influence on safety and financial performance.
Effects of unionisation	((Corsi et al.,	Crash data analysis/	Union membership

Study focus	Author, year	Method/sample	Findings
on safety outcomes	2012)	n = 157,292 US trucking firms	improves driver and vehicle safety performance and crash rates

Four studies in 2 countries from the 1980s to 2012 provide evidence that profitability is associated with:

- Lower driver turnover;
- Lower crash rates; and
- Better driver and vehicle safety ratings.

One study found that owner-drivers are more prone to ill health, stress injury and crashes and one study found that union membership improves driver and vehicle safety performance and crash rates.

Two studies found that proactive safety management improves safety as well as profitability (Fernandez-Muniz et al., 2009; Knipling & Bergoffen, 2011).

In later studies, Corsi et al (2002; 2012) found that unionised drivers work more safely as measured by the US Government's safety performance criteria and have fewer crashes than non-unionised drivers.

Collectively these studies concluded that poor financial performance predicts poor driver and vehicle ratings and increased crash risks. Conversely, good, proactive safety management influences profitability.

Moreover, unionization is positively related to driver and vehicle safety and lower crash rates. Also, owner-drivers are more at risk of OHS risk than small and large company drivers.

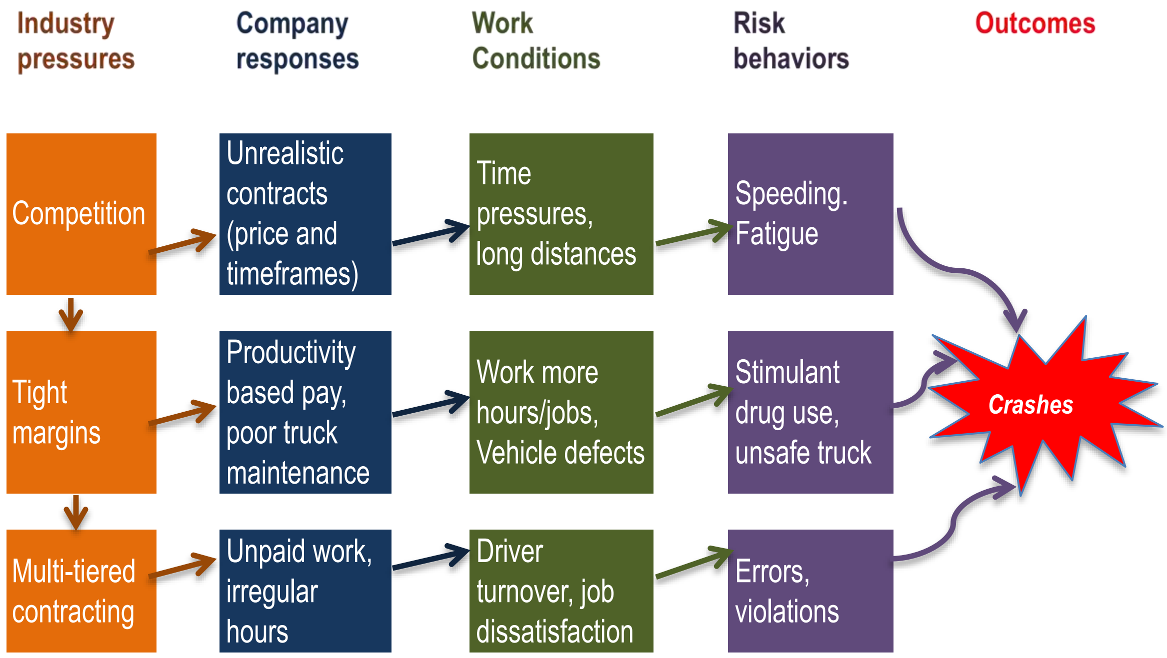
Discussion

Increasingly the transport safety research is identifying the detrimental effects of systemic pressures, such as contingent work arrangements, low job security and low pay, on truck driver health and safety (Mayhew & Quinlan, 2006). With regard to the contingency-work effects on short haul drivers, Williamson et al (2009) found distinctions between sole contractors or owner drivers and casual or permanent employee drivers but did not find differences in OHS outcomes between these groups.

The disproportionate levels of sleep disorders and fatigue in truck drivers is well documented and explained by unusual and unhealthy sleep and rest patterns experienced by drivers due to schedules and general work environments that are too often not conducive to restorative sleep (Adams-Guppy & Guppy, 2003; McCartt, Rohrbaugh, Hammer, & Fuller, 2000; Moreno et al., 2004; Williamson et al., 2001). And while there is little evidence of disproportionate use of alcohol by drivers, the effects of even moderately fatigued driving in terms of decrements to performance has found to be equivalent to illegal and unsafe levels of intoxication (Williamson & Feyer, 2000). In addition, there are elevated morbidity patterns including obesity, diabetes, cardiovascular disease, cancers, musculoskeletal disorders, arthritis, chronic back pain, and depression – all related to environmental conditions that characterise the trucking industry (Apostolopoulos, Sönmez, Shattell, & Belzer, 2012).

In summary, the picture of trucking safety is not a very positive one. The industry, left unregulated, is characterised by inherent safety risks. Figure 1 depicts a model of the trucking industry pressures that link to risk and crash outcomes supported by the findings of this review.

Figure 1. Chain of pressures leading to truck crashes (figure adapted from Williamson, 2014)*



Industry Pressures

At a macroeconomic level the industry pressures include intense competition between trucking operators, tight profit margins and long chains of contracting and sub-contracting. Competition forces even greater downward pressure on margins that in turn lead to unsafe practices. For companies to achieve the operating flexibility to maintain profitability, they very often subcontract drivers to keep their wages commitment as low as possible. With intense competition, trucking companies and drivers are virtually forced to accept unrealistic contracts in terms of price and agreed delivery timeframes, which in turn impose time pressures and long journeys, often resulting in driving at higher speeds and driving while too tired.

Company Responses

Company responses to low profit margins are often to pay drivers based on productivity. More than three quarters of drivers are paid by this method in Australia (Williamson & Friswell, 2013). Productivity pay encourages drivers to work more hours or take on more jobs, leading to the use of stimulant drugs to combat fatigue. In addition, low profitability encourages companies to keep trucks operating when the work is available even when this means skipping maintenance, resulting in defects and unsafe trucks on the road.

The trucking industry is characterised by multi-tiered contracting arrangements, making drivers vulnerable and being pressured to do unpaid work and to work long and irregular hours. This results in a lack of quality leisure and family time, job dissatisfaction and driver turnover.

Work Conditions

All of the industry pressures, and company responses to these pressures described in Figure 1, provide an environment where drivers are under time pressures, drive long distances, work more hours, in vehicles that have mechanical defects. Consequently, there is high driver turnover and job dissatisfaction in the industry.

Risk Behaviours and Outcomes

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* Keynote presentation at Occupational Safety in Transport Conference, Gold Coast, 2014.

In the scenario described above errors and violations are likely to occur. Speeding, fatigue, use of stimulant drugs, vehicle defects, unsafe trucks are all major crash and injury risk factors.

Limitations

This review was not intended to be a comprehensive systematic review of the literature. Rather it aimed to highlight an important safety management characteristic of trucking companies and the industry more generally. Also, while many of the Australian studies examined in this review were cross-sectional, the research methods were sound and findings were statistically robust. This topic warrants more research, especially longitudinal studies.

Conclusions

Whether or not we can accurately describe the trucking industry as “sweatshops on wheels” truck drivers are a vulnerable workforce. Drivers are ‘price takers’ rather than ‘price setters’ because of:

– the length of the sub-contracting chain;
– prevalence of ‘undercutting’ to win work;
– high capital costs of entering the industry;
– tendering processes that have little or no regard for the safety of the transport task;
– limited negotiating ability of drivers;
– small number of large clients; and
– presence of a few large dominant transport companies with the ability to make efficiency and price gains through purchasing power.

There is clearly a relationship between driver payment methods and/or pay levels and risk behaviour and safety outcomes. Safety and efficiency in this industry are influenced by how, when and what is remunerated. Intense competition and low profit margins lead to poor safety conditions for drivers, manifesting in pressure to take driving risks – speeding, working long/irregular hours, driving tired, taking drugs, not doing preventative truck maintenance.

This paper provides a weight of evidence that remuneration and safety are linked in the trucking industry and that this is a fundamental issue that needs to be addressed through specific regulation and perhaps industry reform.

To break this industry-wide conundrum specific regulation is needed to address the pressures that create incentives for unsafe outcomes (fatigue, poor maintenance, speeding, drug-use etc). The pressures that need to be addressed include:

- competition that allows contracts with unsafe deadlines and prices;
- tight margins and freight rates;
- multi-tiered contracts allowing pressures on subcontractors; and
- productivity-based payments, only payment for driving work.

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Who does what, where and why? Optimising allocation of functions in rail level crossing systems

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Abstract

Level crossings represent one of the key strategic risks on railways across the world. Recent research has indicated that collisions at rail level crossings (RLXs) may be better prevented through more sophisticated allocation of functions within these environments. The aim of the research described here was to explore this further and to identify potential design remedies. Cognitive Work Analysis (CWA) is a systems analysis framework that has been successfully used to identify how social and technical components within systems can be configured to enhance overall performance. Two CWA techniques were used to identify design options related to how functions are allocated within RLX systems. Based on an analysis of nine RLXs in metropolitan Melbourne, the findings highlighted an uneven spread of activity across the situations in which train detection and safety can occur and across the actors involved in these functions. The majority of activity currently occurs when users are closest to the RLX. However, there are instances where important activities could occur away from the RLX but typically do not. In addition, the analysis showed that the RLX infrastructure is currently responsible for most functions relating to safety, and there are parts of the system that could be better exploited to support and/or improve behaviour, including humans, in-vehicle systems and the surrounding infrastructure.

Introduction

Level crossings represent one of the key strategic risks on railways across the world. In Australia an average of 37 people are killed at RLXs each year (Australian Transport Council, 2010), incurring an estimated annual cost of around $24.8 million (Cairney, 2003). Similar estimates have been reported in other developed countries including Europe and the US (RSSB, 2014; Federal Railroad Administration, 2014). Recent research in Melbourne, Australia, has indicated that collisions at RLXs may be better prevented through a more sophisticated allocation of functions within these environments. For example, the recent Kerang RLX tragedy would likely have been prevented through the provision of warnings by other parts of the system such as the truck driver’s vehicle (through in-vehicle warnings) or active early warning signage (Salmon et al., 2013). Cognitive Work Analysis, a popular systems analysis and design framework, focuses on optimising social (i.e., human) and technical (i.e., non-human) components within systems. The study described in this paper involved using methods from CWA to examine current and potential allocation of functions to optimise safety at RLXs.

According to some researchers (e.g., Salmon et al., 2015; Read et al., 2013), progress towards improving safety at RLXs has been hampered by a continued focus on system components and countermeasures (i.e., road users, warnings, signage, enforcement etc.) in isolation. However, this ‘broken component’ mentality does not fully take account of the interactions between users and the RLX infrastructure which give rise to unsafe behaviours (Salmon et al., in press). A new line of inquiry is needed to address these types of interactions. Although not commonly applied to the study of RLX safety, (Read et al., 2013; Wilson & Norris, 2005), a systems approach is likely to have the greatest potential for understanding the interactions between humans and technology (Salmon & Lenné, 2015) from which potential design solutions can then be identified.

CWA is a five-phase systems analysis framework that aims to improve design in complex sociotechnical systems (Vicente, 1999), of which RLXs are an example (Salmon & Lenné, 2015). It has been used indirectly to inform various design or redesign activities (e.g., Cornelissen, Salmon, Stanton & McClure, 2015; Jenkins, Stanton, Salmon & Walker, 2011; Stanton & Bessell, 2014; Stanton & McIlroy, 2012) and more directly in a range of design applications including large scale military operations (e.g., Bisantz et al., 2003), teams (Gualiteri, Roth & Eggleston, 2000; Naikar, Pearce, Drumm & Sanderson, 2003), interfaces (e.g., Burns, 2000; Vicente, 1992) and cognitive artefacts (Jenkins, Salmon, Stanton & Walker, 2010). While few designs based on CWA have been formally evaluated, there is evidence that system design can be improved using this framework. For example, task performance, as measured in empirical studies, has been found to improve using designs based on CWA (Reising & Sanderson, 2002; Sharp & Helmicki, 1998). When these designs were evaluated by subject matter experts they were judged to be superior to those using non-CWA methods (Naikar et al., 2003).

All five phases of CWA can be used to inform system design, however this paper focuses only on the second and fourth phases, known as Control Task Analysis (ConTA) and Social Organisation and Cooperation Analysis (SOCA) respectively. ConTA and SOCA were used here to examine how functions are, and could be, allocated within RLX environments in Victoria, Australia as the train driver and the road user approach an actively controlled RLX in a typical metropolitan environment.

Control Task Analysis

Control Task Analysis (ConTA) focuses on recurring activities within systems and examines what is to be achieved independent of how the activity is to be carried out (Vicente, 1999). The Contextual Activity Template (CAT), developed by Naikar, Moylan and Pearce (2006), is used within this phase of CWA. The CAT is a representation of a system's activity in terms of both work functions and work situations. Work situations can be broken down on the basis of recurring work schedules or specific locations (or both). The CAT examines how tasks currently do and could occur in different situations and locations.

An extract of the CAT showing a sub-set of RLX functions and situations is shown in Figure 1. The functions, displayed on the vertical axis, include some of the known functions afforded by the various components of the system. The situations, shown on the horizontal axis, represent the five temporally and spatially separated stages within which the driver could be when the rail user is at the pre-whistle board stage on approach to the RLX. Cells surrounded by dashed lines indicate the situations or stages of approach where a function is able to occur but typically does not, while the cells in which box and whisker diagrams are displayed indicate where functions can and typically do occur. Empty cells indicate that the function is not possible in that situation. For example, the first function shown on the vertical axis, 'visual warning of RLX', can be provided in the earliest approach zone situation 'road user pre-approach', but typically is not (because the road user is too far from the RLX to receive the warning or to see the crossing). However, it typically does occur in the latter four approach zone phases, 'road user on approach', 'road user pre-boom gates', 'road user at boom gates', 'road user on RLX (because the road user is close enough to receive the warning and/or to see the crossing).

Social Organisation and Cooperation Analysis

Social Organisation and Cooperation Analysis (SOCA) is used to examine actual and potential allocation of functions within sociotechnical systems. When applied to the CAT SOCA examines the constraints imposed by allocation of specific actor (both human and non-human) roles to functions in any given situation (Stanton & Bessell, 2014). Different actors are allocated to different functions and the analysis examines who currently does what and who could do what given the constraints of the system (Salmon et al., 2015). This provides useful information about how activity is dispersed within the system, including the balance between activities completed by humans and by technology. In addition, it shows how activities could be allocated differently given design modifications. Within the RLXs examined, the key actors and their related coding are shown in Figure 2. For example, the function 'visual warning of RLX' is currently only performed by the warning/detection systems except when the train passes through the crossing (in this situation the train itself also provides a visual warning). The analyst then asks whether other actors within the system (such as the vehicle through an in-vehicle display) could also perform this function, and also whether this function could be provided in situations where it is currently not but in which the CAT shows that it could be (namely when the driver is in the 'pre-approach' and 'on RLX' situations).

Unlike other human factors methods, the unique contribution offered by CWA for design lies in the identification of constraints imposed by the system on behaviour. This formative type of analysis focuses on modelling how a system could perform given its constraints as opposed to how it should perform or currently performs (Stanton, McIllroy, Harvey et al., 2013). This can provide an optimal allocation of functions analysis which can be useful for prompting system re-design (McIlroy & Stanton, 2011). The aim of the current study then, was to use CAT and SOCA-CAT to examine current and potential allocation of functions within RLX systems as the basis for identifying design options. The analysis focussed on active RLXs (controlled by boom gates, flashing lights and bells) in metropolitan Melbourne.

Method

A CAT was developed to represent a typical metropolitan actively controlled RLX as approached by both the train driver (referred to as the rail user) and a driver (referred to as the vehicle user). Pedestrians and cyclists, passively controlled RLXs, and actively controlled RLXs in rural areas were excluded due to space constraints but have been examined elsewhere as part of the larger research program from which this analysis is derived.

The first step in constructing the CAT involved identifying the situations and functions within the RLX system and how these should best be represented. The situations, as shown along the horizontal axis in Figure 1, depict the spatially and temporally distinct approach phases that the road and rail user will progress through on approach to the RLX. For the rail user these phases are: pre whistle board, at whistle board, at track magnet, at station pre-RLX, traversing RLX, and pre-RLX. (Due to space constraints, only the 'pre-whistle board' approach phase is shown in Figures 1 and 2). For the road user, these phases are: pre-approach, on-approach, pre boom gates, at boom gates/boom gates closing, and on RLX. The functions, as shown along the vertical axis, represent 11 of the 43 different functions provided by the physical objects within the RLX system, such as 'visual warning of approaching train', 'prompt stop/go decision' and 'dissemination of incident data'. For example, physical objects including the flashing light assembly and the boom barriers afford the function 'visual warning of approaching train'. Due to space constraints, this paper focuses only on the functions directly associated with safety and train detection.

The situations and functions were derived by the research team using existing documents and literature from the rail design and rail safety literature as well as inputs from earlier phases of CWA reported elsewhere (Salmon et al., in press). The relationships between each of the functions and the situations in which they occur or could potentially occur were then mapped onto the CAT following the method outlined in the Introduction.

The next step was to construct the SOCA-CAT. This phase involved populating the CAT with the various human and non-human actors to show who carries out the work in the system in which situation. Five groups of actors were identified, namely, the rail user, the vehicle user, warning/detection systems, regulators/authorities, and the physical infrastructure. The rail user comprises the train driver and the train itself. The vehicle user comprises the driver and the driver's vehicle. The warning/detection systems include the flashing light assembly (including the bells and the boom gates), the track magnet (which sets the warning systems in operation once it has been triggered by the train), and static signage and road markings associated with the RLX. The physical infrastructure includes road signage and markings within the vicinity of the RLX as well as the road itself. Regulators/authorities include the personnel responsible for the higher level operation and management of the rail system including the road regulator, the rail regulator, the road infrastructure owner, the rail infrastructure owner, the government and the police. The shaded CAT (SOCA-CAT) with the key for the different actors is shown in Figure 2.

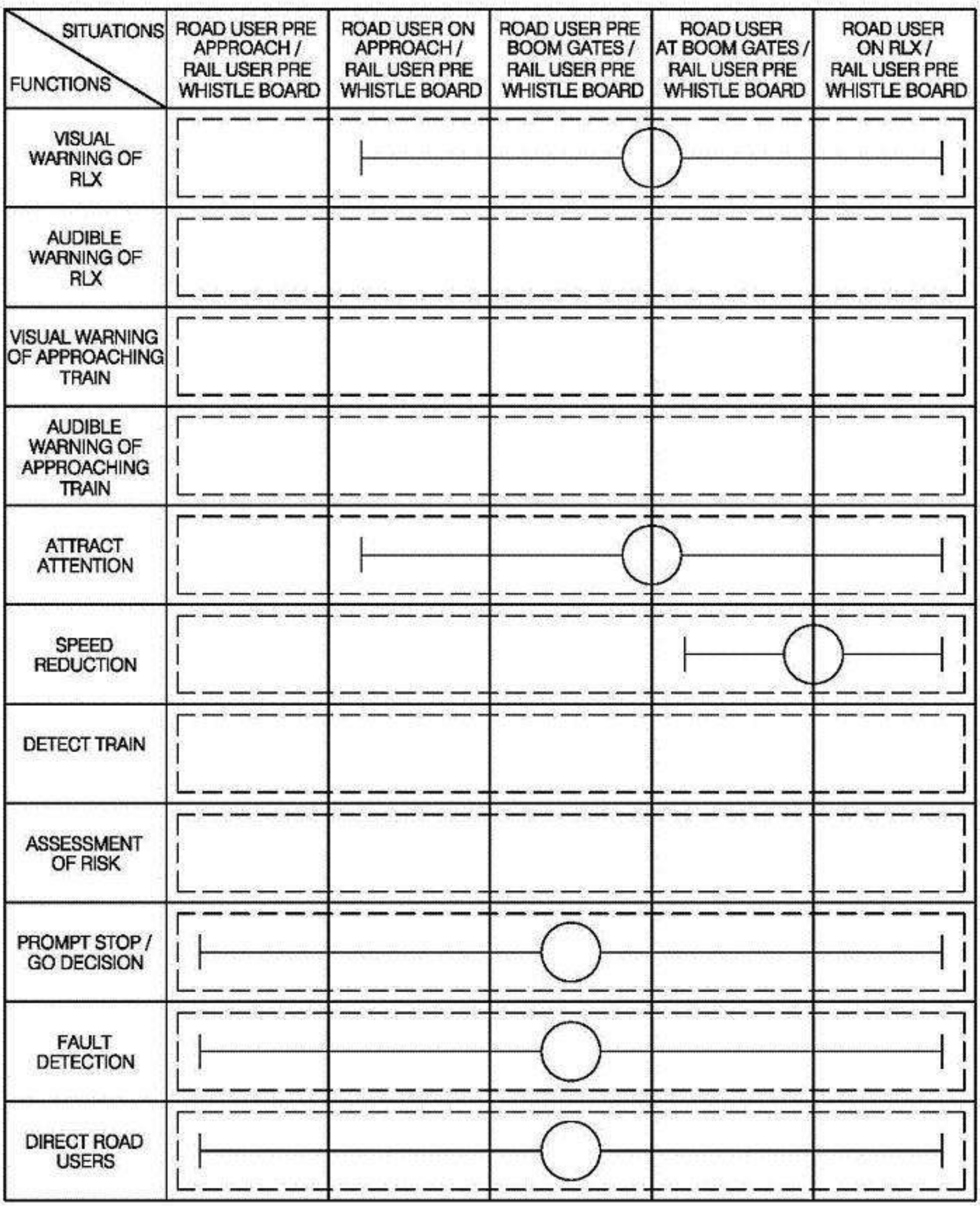

Figure 1. Extract of CAT for approaching an actively controlled metropolitan RLX

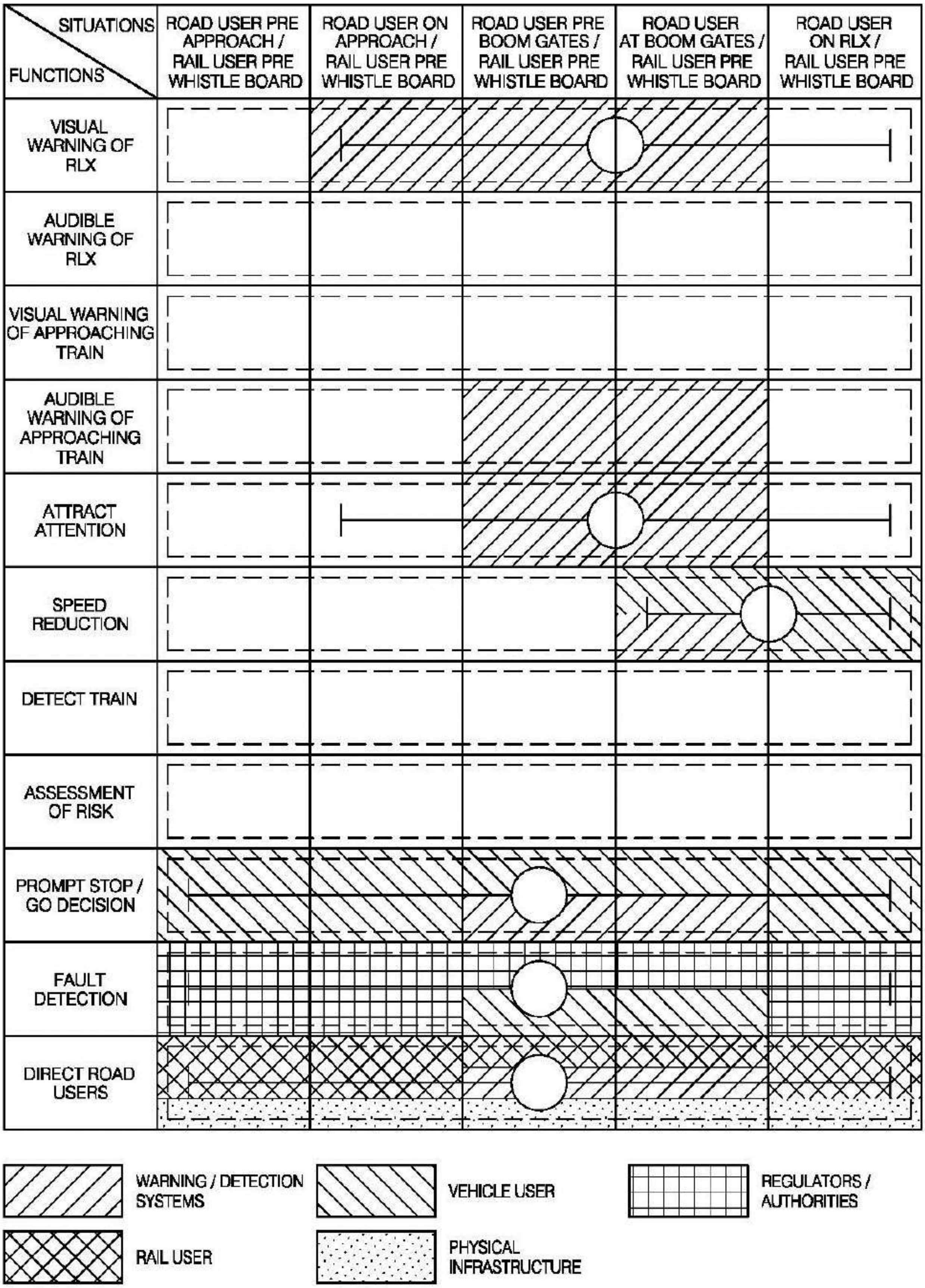

Figure 2. Extract of SOCA-CAT for approaching an actively controlled metropolitan RLX

The CAT and SOCA-CAT were refined on the basis of the data collection activities outlined below, and the formative SOCA analysis was conducted following the approach outlined in the Introduction.

On-road studies of driver behaviour

An on-road study of driver behaviour at RLXs was undertaken. The study focussed on metropolitan active RLXs in Melbourne's south eastern suburbs. Twenty-nine drivers aged 18 – 55 years (M=30.5, SD = 11.1) drove a pre-defined route incorporating nine actively controlled RLXs. Participants provided 'think aloud' verbal protocols as they negotiated the route. The on-road study was particularly useful for verifying the road user situations on approach to the RLX.

Train driver focus group and in-cab familiarisation

A focus group was held with two train drivers and one rail subject matter expert to gather information regarding train driver behaviour at RLXs. Participants were asked to describe their behaviour on approach to the RLX along with the constraints influencing behaviour. In addition, three of the co-authors participated in train cab rides through urban and regional areas to gain familiarisation with the train-driving task and to understand the train driver perspective on approach to RLXs. These activities were particularly useful for verifying the situations on approach to the RLX for the train driver.

Subject Matter Expert workshop

A subject matter expert workshop was conducted with 11 stakeholders from rail and road safety organisations (including representatives from the state road authority, the rail regulator, relevant state government departments, train service providers and transport safety investigators). The workshop was particularly useful for refining the functions within the RLX system.

Results

Contextual Activity Template

A number of observations can be made on the basis of the CAT. First, there are only a very small number of functions (16%) that are not able to be supported across all of the situations on approach to the RLX (as indicated by the empty cells). In most cases this is of little concern since these functions are typically not relevant to the situations in which they do not occur. For example, 'exit from track' which provides a safe means for exiting the crossing for road users trapped on the RLX is only possible when the road user is actually on the tracks. 'Optimise warning time' which provides the required minimum amount of time to inform the road user that a train is approaching can only occur once the train has activated the track magnet to trigger the active warning signals; therefore it cannot occur in any situation prior to this.

Second, more of the activity within the system occurs in those situations where both the road user and the rail user are closer to the RLX. For example, 17 (73%) of functions occur when the road user is at the boom gates and the rail user is at the track magnet compared to only 5 (21%) of functions when the road user is in the pre-approach zone and the rail user is pre-whistle board. Across all six rail user approach zone phases, the distribution of functions is similar, with the most functions occurring when the road users is at the boom gates, and the least occurring when the road user is in the pre-approach zone.

Third, in all situations, there are a number of functions that could occur but typically do not (as indicated by the dashed boxes). These potentially represent opportunities for redesign. Most of these functions could occur in situations when the RLX is inactive and/or when the road and rail user are furthest from the RLX. For example, when the rail user is pre-whistle board (i.e., crossing inactive), 47% of functions are possible when the road user is in the pre-approach zone compared to 34% of functions when the road user is at the boom gates. When the rail user is at the track magnet (crossing active), 39% of functions are possible in the road user pre-approach zone compared to 13% when the road user is at the boom gates.

Most of these functions are associated with warnings of the RLX or the train's approach (or related functions including attract attention, speed reduction, detect train and assessment of risk), and do not typically occur in situations when the rail and road user are farthest from the RLX. For example, the only situation in which visual warning of the RLX is not currently provided to road users but potentially could be is when the road user is in each of the pre-approach situations. This is because the road user typically cannot yet see the RLX or the warning signs on this early phase of approach due to the presence of visual clutter and heavy traffic in the metropolitan environment which obscures the driver's view. For similar reasons, audible warning of the RLX is not typically afforded in situations other than when the road user is on approach or just prior to the boom gates because the road user will typically not be able to hear the warning bells and/or the train's approach. Assessment of risk and detect train could but typically do not occur before the train has reached the track magnet because the road user will not yet know that a train is approaching and the rail user will not yet be approaching the RLX.

Social Organisation and Cooperation Analysis Contextual Activity Template

The SOCA CAT found that almost 60% of the activity within the system is carried out by the warning systems, followed by the vehicle user (29%) and then the rail user (23%). The physical infrastructure performs almost 13% of the work, while the regulators/authorities perform about nine percent. The share of activities carried out by the driver and the vehicle is about even for the rail user group, but the driver carries out a larger proportion of the work within the vehicle user category (56% driver versus 43% vehicle). Overall, the majority of functions within the metropolitan RLX system are currently being performed by technology, with relatively fewer functions carried out by humans.

SOCA-CAT formative analysis

The formative SOCA-CAT analysis involved making an assessment as to whether the workload within the system could be redistributed across situations and/or reassigned to different actors and artefacts to optimise system functioning. To summarise, a number of possible re-design options were identified.

First, the CAT showed that most of the activity for key system functions associated with safety and train detection occurred when both the road user and the rail user were at the RLX. Although these functions were able to take place earlier in time and place, they typically do not. This raises the question as to whether more of the activity that normally occurs at the RLX could take place earlier. For example, visual and audible warning of the RLX could be provided to road users during the pre-approach zone phase via active signage or an in-vehicle warning. This would potentially overcome the problem of visual and audible clutter that is typical in metropolitan environments, and re-assign some of the workload from the warning systems to the vehicle itself. Road users would then be prompted to look out for the RLX earlier and prepare to stop if necessary. This would also assist drivers to prepare for, or carry out, other related functions earlier including speed reduction, assessment of risk, and prompt stop/go decision, all of which can only happen when the RLX is within the driver's line of sight. The in-vehicle warning device would have a similar effect when used to warn of the train's approach. In this case it would permit the occurrence of functions including 'detect train', 'visual warning of approaching train' and 'auditory warning of approaching train' earlier than in the situations in which they typically occur (i.e., before the train has reached the track magnet and triggered the active warnings).

Second, there is potentially scope for actors not directly responsible for functions related to safety and train detection at the RLX itself to play more of a role in optimising system performance. These actors include the physical infrastructure and environment which currently account for only 13% of the system's activity, and the regulators/authorities which currently account for less than ten percent of it. For example, a pedestrian shelter and hub area with amenities close to the RLX may increase the likelihood that pedestrians will gather there to wait for the train (rather than hurry across the RLX), which in turn could have benefits for approaching motorists including slowing down and being alerted to the presence of the RLX. The presence of a person to act as a representative from the regulators/authorities group such as a crossing supervisor during peak periods would provide similar benefits. Both of these actors would potentially shift the allocation of train detection and safety functions from the RLX infrastructure, the vehicle and the driver alone.

Discussion

The study described in this paper involved using methods from CWA to examine current and potential allocation of functions within metropolitan actively controlled RLXs. The outcomes give pointers to improve safety at RLXs by identifying how social (i.e., human) and technical (i.e., non-human) components within the system can be optimally configured. A number of important findings emerged from the analysis.

First, the results highlighted an uneven spread of activity across the situations in which train detection and safety can occur and, second, across the actors involved in these functions. Specifically, the CAT showed that the majority of activity related to train detection and safety currently occurs when the rail user and the road user are closest to the RLX. Conversely, the majority of situations where this type of activity could occur but typically does not are those in which the road user and the rail user are farthest from the RLX. An in-vehicle system designed to provide advanced warning of the RLX and/or the approaching train was suggested as a potential design option for re-allocating some of the functions relating to train detection and safety earlier than when they would normally occur. The intention of the design is to provide more time for road users to prepare for the RLX, with the overall goal that they will be more likely to notice the crossing and stop safely if necessary.

The SOCA-CAT showed that the RLX infrastructure is currently responsible for most functions relating to safety, and there are parts of the system that could be doing more to support and/or improve behaviour, such as humans, in-vehicle systems and the surrounding physical infrastructure. An in-vehicle warning system would potentially help re-distribute some of the workload from the RLX infrastructure, thus providing another layer of protection for those users who might otherwise overlook the RLX by relying on the active warning systems alone. Implementation of a crossing supervisor and pedestrian hub/waiting area could potentially provide similar benefits.

This study is not the first to call for new designs to improve safety at RLXs, and a number of researchers (e.g., Larue et al., 2014; Tey, Wallis, Cloete, Ferreira & Zhu, 2012) have already tested a range of emerging intelligent transport systems, including visual and auditory in-vehicle warning systems. The results of these simulator studies generally showed increased compliance and earlier reduced approach speeds at passive RLXs, although only marginal improvements in behaviour at active RLXs were found when compared to baseline conditions (i.e., no in-vehicle warning). Overall, drivers found the in-vehicle warning systems to be useful, easy to use, and socially acceptable (Larue, Rakatonirainy, Haworth & Darvell, 2015). The designs proposed in the current study are currently being refined through discussions with subject matter experts and will then be tested in a simulator as part of the larger project from which this study is derived. It is planned that the in-vehicle warning system will be examined both alone and in combination with other re-designs including the crossing supervisor and pedestrian hub/waiting area.

Although CAT and SOCA-CAT have been useful for mapping out the problem space in an explicit manner, it will be important to examine any potential threats to safety that might arise from allocating functions to situations where they are not currently afforded. For example, in busy metropolitan environments, provision of an early in-vehicle warning could compete with other driving tasks that take a higher priority for the driver's attention during the pre-approach zone, such as a pedestrian darting out in between parked cars or traffic lights changing from green to red. Aside from the issue of distraction, drivers may also become desensitised to a warning if it is given too early such that they fail to pay attention to the RLX at the time when it becomes critical to do so. Larue et al. (2014) did not identify any issues associated with the in-vehicle devices in terms of driver distraction or increases in driver workload, although at actively controlled crossings these effects were examined only when the active warnings had commenced activation and the driver was within the vicinity of the RLX. The simulation studies to be conducted as part of the larger research program will examine driver behaviour at all stages on approach to the RLX.

Due to space constraints, the current analysis was restricted to metropolitan actively controlled RLXs and focussed on drivers only. The wider research program also examined the distribution of activity in a sample of ten passive RLXs, and both motorised and non-motorised road users were included in the analysis for active and passive RLXs. New designs incorporating the outputs of these analyses will also be examined in the simulator as part of the larger research program.

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The social impacts of a road safety education program

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Abstract

As well as targeting knowledge, skills and attitudes of young peoples' road risks, road safety education programs can influence a wider circle of stakeholders and, if this occurs, support the broad range of community road safety measures.

Around 50,000 senior high school students attend the RYDA program each year in Australia and New Zealand. During the recent RYDA revision process, data was collected on indirect impacts on road safety attitudes suggesting wider social value of the program. Stakeholders surveyed included teachers (n=180), parents (n=60), facilitators (n=118) and community volunteers (n=55). Survey responses were voluntary. Teachers were approached at programs while Rotary volunteers/facilitators were asked via email. Parents were contacted via schools.Questions focused on RYDA stakeholders' sense of purpose, driving behaviour, and knowledge of road safety and any other outcomes that could contribute to the overall social value of the program.

Findings are that stakeholders, to varying degrees, report personal satisfaction from helping young people stay safer, increased knowledge and awareness of road safety issues, and sharing of road safety knowledge and skills. Teachers report increased awareness of road safety issues (75%), personal satisfaction from helping learner drivers to be safer on the road (59%) and increased road safety knowledge and skills to share with family and friends (44%).Volunteers (93%) and facilitators (86%) reported personal satisfaction from helping learner drivers to be safer on the road. Parents reported feeling their child was safer on the road (44%) and that they have indirectly increased awareness of road safety issues (37%).

Introduction

As well as targeting knowledge, skills and attitudes of young peoples' road risks, road safety education programs can influence a wider circle of stakeholders and, if this occurs, provide support for the broad range of community road safety measures.

Around 50,000 senior high school students attend the RYDA program each year in Australia and New Zealand. Designed for Year 11/12 students (depending on jurisdiction), it is an attitudinal program designed to raise awareness of both road and personal risks that contribute to crashes, and enable young drivers and passengers to develop strategies for taking action to reduce their risks in future.

The aim of the study was to trace and investigate further the different levels of social impact the program has. While reference will be made to direct impacts on students, I am equally interested in the indirect impacts on teachers (who attend the program with their students), parents (with no direct involvement, but we know through survey data that home conversations occur as a result of their child's attendance), facilitators (these are contracted and trained to deliver particular RYDA sessions), and Rotary volunteers (acting as organisers in regional areas, day managing the program, and providing logistical support on the day).

The RYDA program consists of six 30 minute linked sessions focusing on different aspects of road and personal risk with an opening and closing address. Students use a Goals, Plans and Strategies workbook (GPS) for the day designed to record facts, thoughts and actions, and for follow-up at school and home.

The sessions are:

Rights & Responsibilities - Key risk areas for young drivers and passengers plus the role of the police. Features impactful videos on decision making.

After the Crash - A presentation by a speaker about the crash that changed their life. Students reflect on how a similar crash would affect their life

Genevieve's story - The story of two girls who made one bad decision, and its ripple effect. Students workshop how to plan ahead for high stakes decision-making.

Speed & Stopping - Practical demonstrations of the physics of speed, stopping and following gap, as well as car safety features and maintenance.

Hazards & Distractions - Strategising to manage distractions and improve hazard perception skills.

The Personality Test - Personality and mind-state role in road risk. Students identify five personality areas, self-assess against them and explore how they may affect their driver or passenger behaviour.

The student learning outcomes are:

- Understand road risks and reflect on long-term life consequences of a crash
- Identify crash factors and realise how they are preventable
- Appreciate how personal factors affect risk
- Develop personal strategies and plans, and consider self-monitoring of actions long term
- See driving as a social responsibility and recognise the protective role of road safety measures, especially the graduated licensing system

The developers used best-evidence road safety education principles supported by an academic Advisory Council in the recent program revision.

Method

During the RYDA revision, data was collected from program stakeholders on indirect impacts on road safety attitudes in relation to the wider social value of the program.

Stakeholders surveyed included teachers (n=180), parents (n=60), facilitators (n=118) and community volunteers (n=55). Survey responses were voluntary. Teachers were approached at programs while Rotary volunteers and facilitators were asked via email. Parents were contacted via schools. Questions focused on RYDA stakeholders' sense of purpose, driving behaviour, and knowledge of road safety and any other outcomes that could contribute to the overall social value of the program.

Discussion

The study's key finding is that stakeholders, to varying degrees, report personal satisfaction from helping young people stay safer, increased knowledge and awareness of road safety issues, and sharing of road safety knowledge and skills.

Teachers report increased awareness of road safety issues (75%), personal satisfaction from helping learner drivers to be safer on the road (59%) and increased road safety knowledge and skills to share with family and friends (44%).Volunteers (93%) and facilitators (86%) reported personal satisfaction from helping learner drivers to be safer on the road. Parents reported feeling their child was safer on the road (44%) and that they have indirectly increased awareness of road safety issues (37%).

Conclusion

Any road safety education program has an impact depending on its size, whether its content represents best-practice principles, how it is organised, and follow-up message prolongation activities. The study is a starting point for further investigation of how a road safety education program can contribute value to the broad range of road safety measures in the community. The study's findings provide detail about how this works, and how the different stakeholders may take action as a result of the influence of their specific involvement. The research will be continued to assess more specifically the flow-on effects of these influences.

Determinants of Road Traffic Safety: New Evidence from Australia using a State-Space Analysis

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Abstract

This paper examines determinants of road and traffic crash fatalities in Queensland in the 1973-2007 period using a state-space time-series model. In particular, we investigate the effects of policies that aimed to reduce drink-driving and economic environment to traffic fatalities. The results show that random breath testing reduced fatalities by 10 per cent and that the zero BAC for young drivers reduced fatalities by 15 per cent. Reductions in economic activity also lead to reductions in road fatalities, estimating that a one per cent increase in the unemployment rate leads to a reduction of traffic fatalities of 0.22 per cent.

Key words: Road traffic crashes, safety, alcohol, young drivers, state space, Queensland

Introduction

It is well known that drink-driving has long played a substantial role in road traffic crashes, injuries and deaths, especially among young drivers (Renwick et al., 1982; Mayhew et al., 1986; Zador et al., 2000; Voas et al., 2006; Ramstedt, 2008). Over the past four decades, governments in Australia have implemented legislative change and enforcement measures that are designed to reduce the road toll and improve traffic safety. In relation to drink-driving in particular, the legal limit of blood alcohol concentration (BAC) for drivers was reduced from 0.08 (i.e., 80 milligrams of alcohol per 100 millilitres of blood) to 0.05 in 1983, which resulted in significant reduction of road accidents involving drink-driving (Smith, 1986, 1988). Many other policies that target driving under the influence of alcohol have been implemented since the introduction of a lower BAC limit. In particular, the random breath test (RBT) program was introduced in 1988 and was expanded in 1997 to deter drink-drinking. In 1991, a "zero tolerance" policy was introduced for drivers under the age of 25, who are required to have a BAC of zero when driving a motor vehicle. . The literature on this topic has shown that effects of policies on alcohol-impaired driving may vary by jurisdiction, especially as different jurisdictions implemented such measures at different times and different ways. Estimates of the effects of such policies by jurisdiction are thus worthwhile (Mann et al., 2001; Goss et al., 2008), but to the best of our knowledge, the effects of these measures have not been estimated for Queensland. Our contribution is to examine the effects of the policies that governments have used over the past few decades to reduce the influence of alcohol on traffic fatalities in Queensland. We do so using annual data for the period 1973-2007 period and applying a state-space time series model to control for effects of unobserved components in road traffic fatalities. Our estimates suggest that these policies – the implementation of which is typically resource-intensive – did indeed have a profound effect on road traffic fatalities in this jurisdiction. While we do not attempt to conduct a cost-benefit analysis (CBA) here, we suggest that as a next step in this program of research.

Literature review

The association between alcohol and road traffic fatalities has been investigated wide. At the time of writing, a search on the term "alcohol and traffic accidents" produces 283 results (or approximately 118,000 results when the quotation marks were dropped) in Google Scholar. Therefore, in this section we focus on summarizing results from meta-analyses and review only those studies that are the most relevant to our objectives in this paper. Jones and Joscelyn (1978) was the first study to review the association between alcohol and traffic safety. One of their findings was that young male drivers are at high risk of driving under the influence of alcohol. Mayhew et al. (1986) focused on reviewing three groups of studies: the extent of drink-driving by youth, alcohol use among young drivers who were involved in road crashes, and the relative risk of crashing by young drink drivers. They found that young drivers under the influence of alcohol were more likely to be involved in road crashes than their sober peers. They proposed two hypotheses in connection to this observation: first, that young drivers were "inexperienced" with drink-driving; and second, that after drinking young drivers systematically engaged in more risky behaviour. A meta-analysis by Erke et al. (2009) to determine the effect of driving under influence (DUI) checkpoints in reducing crash numbers across Australia, New Zealand, USA, Canada and the Netherlands indicated the Australian random breath test (RBT) to be the most effective in reducing crashes. Overall, they found the DUI checkpoints to be effective in reducing the alcohol related crash numbers by a minimum of approximately 17 per cent.

Mann et al. (2001) reviewed the effects of lower BAC on traffic accidents and consequences. They revealed that most studies showed beneficial effects of lowering BAC limits on traffic safety measures but these effects varied in magnitude and duration of effect (i.e., with some having temporary and others having lasting effects). In addition, they found that the beneficial effects shown by most studies are due to general deterrence, i.e., they are not restricted only to lowering the BAC limit.

We agree with others who have written on this topic that it is difficult, if not impossible, to differentiate effects of different road safety policies that were introduced during the same period of time. Nevertheless, reviews by Shults et al. (2001) and Goss et al. (2008) have found that two-thirds of the studies of this kind find significant reductions in fatal crashes due to increased enforcement. The review by Zwerling and Jones (1999) also suggest that a zero tolerance towards drunk driving by young drivers is also a very effective way to reduce alcohol-related fatalities, and several more recent studies also corroborate this argument (Voas et al., 2003; Liang and Huang, 2008; Chang et al., 2012).

The traffic safety literature also shows that young male drivers are the most likely to be involved in accidents and to drive under influence of alcohol (Renwick et al., 1982; Lloyd, 1992; Ramstedt, 2008), and hence, policy interventions to lower risk of this group may be expected to be the most beneficial. The main factors that lead to the relatively higher risks to young drivers include the development process from adolescence to emerging adults and differences in risk perception. Arnett (2002), for instance, has argued that young males have higher levels of testosterone and these are also linked to risky driving behaviours. They argue that young males are hence more aggressive and tend to engage in (what they believe to be) shows of bravery and toughness, especially in the presence of young females. Thus, young male drivers appear often take more risk on the road in the presence of passengers (Preusser et al., 1998), especially young female passengers (Simons-Morton et al., 2005). Other explanations of the higher rate of involvement of younger people in serious crashes include an optimistic bias, whereby young drivers overestimate their driving skills and hence take more risk than do other age groups (Tränkle et al., 1990). The results from previous studies (Voas et al., 2003; Carpenter, 2004; Chang et al., 2012) broadly support this view.

In Australia, most previous studies also suggest that lower BAC limits have improved traffic safety. For example, Homel (1994) and Smith (1988) found that the reduction of BAC limits from 0.08 to 0.05 was associated with a significant reduction in traffic fatalities in both New South Wales and Queensland. More recently Howard et al. (2014) reviewed the implications of Australian alcohol policy on public health and found evidence that RBT, lowered BAC limits and low BAC for young drivers were highly effective counter measures. Evidence from Begg et al. (2007) suggests nearly 336 fatalities among young Australians each year and that 31 per cent of these are alcohol-related. Gruenewald et al. (1999) and Chikritzhs and Stockwell (2006) found that increased alcohol consumption and later trading hours of hotels in Perth, Western Australia, were also associated with more crashes by drinking-impaired drivers. Yakovlev and Inden (2010) have also recently found that alcohol consumption (along with air temperature and precipitation) was one of the strongest determinants of traffic fatalities in the U.S. from 1982 – 2006, in the 48 contiguous states.

The role of the business cycle is not always controlled in quantitative studies, but there is reason to believe that doing so may be important. Leigh and Waldon (1991), for instance, hypothesized three possible effects of unemployment on fatalities. First, as aggregate unemployment increases, driving and fatalities should decrease. Second, the effect of unemployment on drinking per se is ambiguous: some unemployed may drink more due to stress, but lower incomes may lead to less drinking, making the net effect uncertain. Third, unemployment may increase aggregate levels of stress and unhappiness, perhaps leading to poorer concentration, perhaps leading to more crashes and fatalities. Using US data by state the authors found evidence in support of two of these hypotheses: holding vehicle miles constant, unemployment increased road crash fatalities (the stress hypothesis), but because unemployed people drove less, there were fewer fatalities overall. Ruhm (1995) has also examined the effects of macroeconomic conditions on alcohol consumption and found them to be pro-cyclical.

Finally, in relation to the methods that have been used in this literature on the relationship between alcohol and traffic safety, we found state-space time series models to be under-represented, even though models from the same family (e.g., structural time series) are fairly common (Bergel-Hayat, 2012; Commandeur et al., 2012). The main difference between structural time series models and the autoregressive integrated moving average (ARIMA), which is also widely applied in traffic safety studies, is the treatment of unobserved components such as trends, slope, cycles and seasonality. Structural time-series models aim to estimate the variance/covariance of these components, while in ARIMA modelling the objective is to remove these components using methods such as first-differencing. Here, we apply a state-space method from the structural time series family to examine the effect of policy interventions that address drink driving in the State of Queensland, Australia.

Methodology

We estimate the determinants of traffic safety based on the latent risk model by Bijleveld et al. (2008), which states that losses can be decomposed into exposure to risks and outcomes of risk. In this study, we use the amount of petrol consumed as our indicator of exposure risk, the outcomes of this risk are indicated by the number of crashes, and the losses due to crashes are indicated by the number of traffic fatalities. Since the indicator variables we use may contain measurement errors, unobserved level, slope, seasonal effects and other exogenous factors (i.e., regression effects), we apply a state-space model[1] introduced by Harvey and Durbin (1986) to estimate unobserved components (e.g., level and slopes) and determinants (e.g., weather and socio-economic conditions) of traffic fatalities as follows:

$$\begin{cases} \log F_t = \mu_t^1 + \eta \log A_t + \gamma^1 \log X_t^1 + \varepsilon_t^1 \\ \mu_t^1 = \mu_{t-1}^1 + \beta_{t-1}^1 + \tau_t^1 \\ \beta_t^1 = \beta_{t-1}^1 + \xi_t^1 \end{cases} \quad (1)$$

$$\begin{cases} \log A_t = \mu_t^2 + \varphi \log E_t + \gamma^2 \log X_t^2 + \varepsilon_t^2 \\ \mu_t^2 = \mu_{t-1}^2 + \beta_{t-1}^2 + \tau_t^2 \\ \beta_t^2 = \beta_{t-1}^2 + \xi_t^2 \end{cases} \quad (2)$$

$$\begin{cases} \log E_t = \mu_t^3 + \gamma^3 \log X_t^3 + \varepsilon_t^3 \\ \mu_t^3 = \mu_{t-1}^3 + \beta_{t-1}^3 + \tau_t^3 \\ \beta_t^3 = \beta_{t-1}^3 + \xi_t^3 \end{cases} \quad (3)$$

where:

- F_t is the number of road traffic fatalities: an indicator of risk losses;
- A_t is the number of traffic accidents: an indicator of risk outcomes;
- E_t is the amount of petrol consumed: an indicator of risk exposure;
- Superscripts 1, 2 and 3 represent components of equations 1, 2 and 3, respectively;
- μ_t and β_t are the unobserved level and slope, respectively;
- X_t^1, X_t^2 and X_t^3 is the set of exogenous covariates such as economic activities and traffic safety interventions, which may differ among equations 1, 2 and 3; and
- ε_t^1, ε_t^2 and ε_t^3 are random noises, which are assumed not to be mutually correlated, with variances $\delta_{\varepsilon^1}^2$, $\delta_{\varepsilon^2}^2$ and $\delta_{\varepsilon^3}^2$, respectively.

In each of Equations 1, 2 and 3 above, the first sub-equation is referred to as an “observed” equation whilst the last two sub-equations are called “state” equations. Both the level and slope components of these equations are assumed to follow normal distributions with zero means and non-zero variances. Observations from the three equations above also suggest that the estimation of Equation 1 alone may produce biased results because the assumption that regressors are independent are violated (i.e., log A_t correlates with $\log X_t^2$, which include some components of $\log X_t^1$). Estimating Equations 1, 2 and 3 simultaneously provides the additional benefit that we are able to estimate the variances and covariance between unobserved factors (i.e., the levels and slopes).

Parameters of exogenous variables and policy interventions in a state-space model can be interpreted in a way that is similar to that of standard log-log ordinary least-squares regression. For example, the parameters of continuous variables (e.g., GSP per capita, rainfall) can be interpreted as elasticities while the parameters of policy interventions represent the aggregate impacts of the interventions on traffic fatalities.

Compared to the standard regression approach, though, the main difference of the state-space model is that the level (i.e., constant or intercept) components are permitted to change over

[1] This is also referred to in the literature as “unobserved component” or “multivariate structural time series” model. For more detailed discussions of this method, see for example Durbin and Koopman (2001).

time at different rates. Thus, in the special case that the variance of the level and slope of the above system are equal to zero, a standard OLS approach can be applied.

Data

Sources of data

The data that are used in this study were collected from several sources including the Australian Bureau of Statistics, the Australian Bureau of Meteorology, Queensland Statistics, and Queensland Transport. Despite our considerable attempts, we simply could not however obtain information on the number of accidents and injuries for 1990 and 1991. The missing data for these years have been imputed by interpolating data from the closest two years. The data on vehicle kilometres travelled (VKT) also have a number of missing observations. In general, VKT data are missing at every 3 to 5 years. On the basis of this source of measurement error, we decided not to use this variable even though it is widely used in the literature as a measure of exposure to accidents. Other variables that we would like to have included, such as unemployment and petrol consumption, were not available from 1966 and 1973, respectively. Before that period, these variables were only available one every four to five years. Therefore, we decided to conduct the analysis from 1973, from which time all of the variables of interest to us are available.

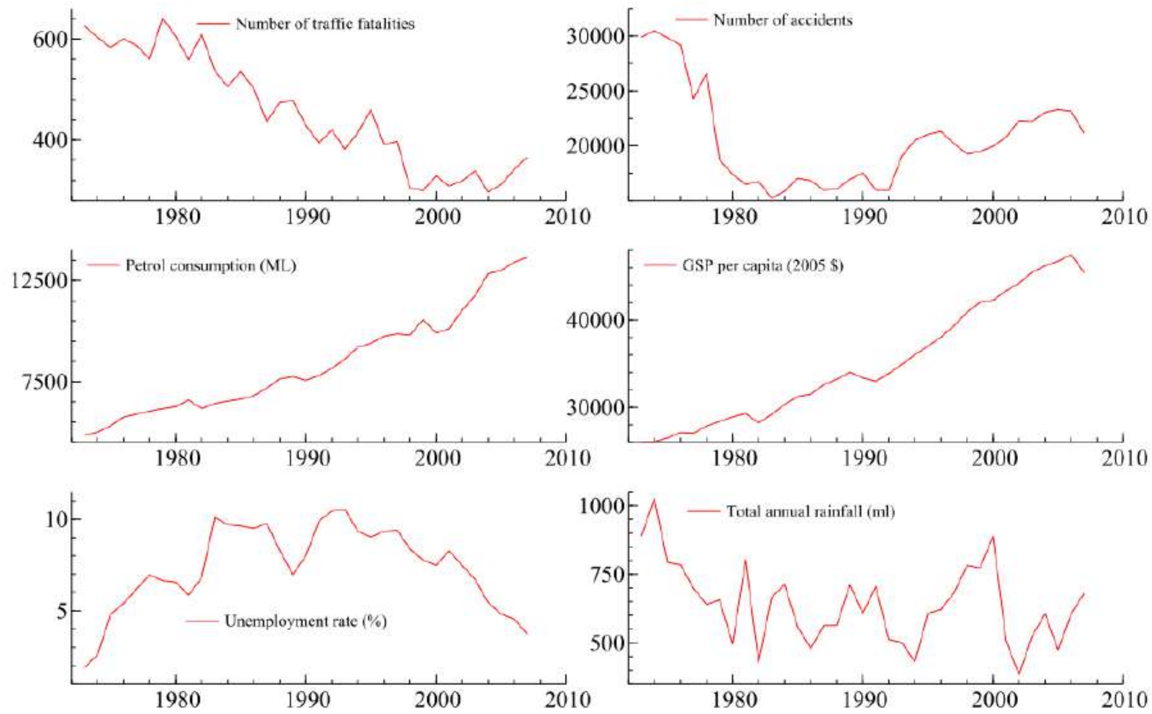

Figure 1. Main variables

Figure 1 shows that during the study period traffic fatalities in Queensland declined continuously, with the exception of several outlier years (e.g., 1980, 1995 and 2007). However, the number of accidents fell sharply in the late 1980s and remained very low until the early 1990s after which time it has generally increased to the end of the series. Another notable observation is that our indicator of economic development–which is measured by the real Gross State Product (GSP) per capita–is almost monotonically increasing, as is the level of petrol consumption (which is our proxy for traffic exposure). The unemployment rate shows a slight increase in the study period whilst the annual rainfall declined slightly. Overall, observations from the actual data seem not to reveal any clear relationship except that higher economic development is strongly associated with exposure.

Variable selection

Since it is not possible to examine the effects of the many legislative changes that were introduced during the study period using the available data (especially when these measures overlap), we focus on two periods when major policies that aimed to address the drink-driving were introduced. The specific interventions of interest are as follows:

- The introduction of random breath testing on 1 December 1988;
- The imposition of a zero blood alcohol concentration (BAC) limit on learner drivers and young drivers in the first three years of having a driver licence (up to 25 years old) on 1 January 1991;
- The random breath test program's expansion in 1997; and
- The “Safe4life” road safety strategy that was introduced in Queensland in 2004, which gave priority to addressing driving under influence of drugs and alcohol, which was the leading cause of traffic fatalities in the state.

We expect these alcohol-targeted interventions to produce greater effects on traffic fatalities, even if their effects on accidents and traffic exposure are less obvious. The rationale for being uncertain about the effects of these policies on accidents *per se*, is due to risk compensation theory (Wilde, 1988, 1998), which suggests that when the likelihood of accidents reduces, people may decide to drive in a way that is actually more risky.

Apart from policy interventions, environmental factors such as weather condition and economic activities can affect traffic safety. The best proxy for weather conditions that is available to us is the total rainfall. Rain deteriorates driving conditions, and hence, the likelihood of traffic accidents and fatalities should increase as a result. Yet, heavy rainfall may also make people less likely to drive, and to take greater precautions when driving, so the net effect of this driving conditions proxy is an empirical matter.

We expect economic activities have positive association with traffic fatalities. An increase in economic activities increases the demand for transport and travel, which may also lead to more traffic crashes and casualties. In this study, we choose gross state product (GSP) per capita at 2005 prices, and unemployment rates as measures of economic development and activities. We expect unemployment rates to be negatively associated with traffic injuries and for GSP per capita to follow an inverse U-shaped relationship in relation to traffic fatalities. Previous studies such as Kopits and Cropper (2005), Bishai et al. (2006) and Iwata (2010) suggested that the relationship between income and traffic fatalities becomes negative when income per capita reaches $6000 to $18000. On that basis, one may hypothesise that the relationship between GSP per capita and traffic fatalities in Queensland will be negative as income per capita in Queensland for the study period was between $30,000 and $50,000 (see Figure 1).

Results and discussion

The results show that residuals of three regressions satisfy the assumptions of homoscedasticity, normality and serial independence at the five percent level. In particular, we apply the Ljung and Box (1978) Q test, the $H(m)$ test (Jarque and Bera, 1980), and the Bowman and Shenton (1975) N-test test the assumptions of serial independent, homoscedasticity and normality, respectively. Graphically, these residuals lie within the intervals (± 2/ n = ± 0.34) and do not deviate much from that of the normal distribution (see Figure 2).

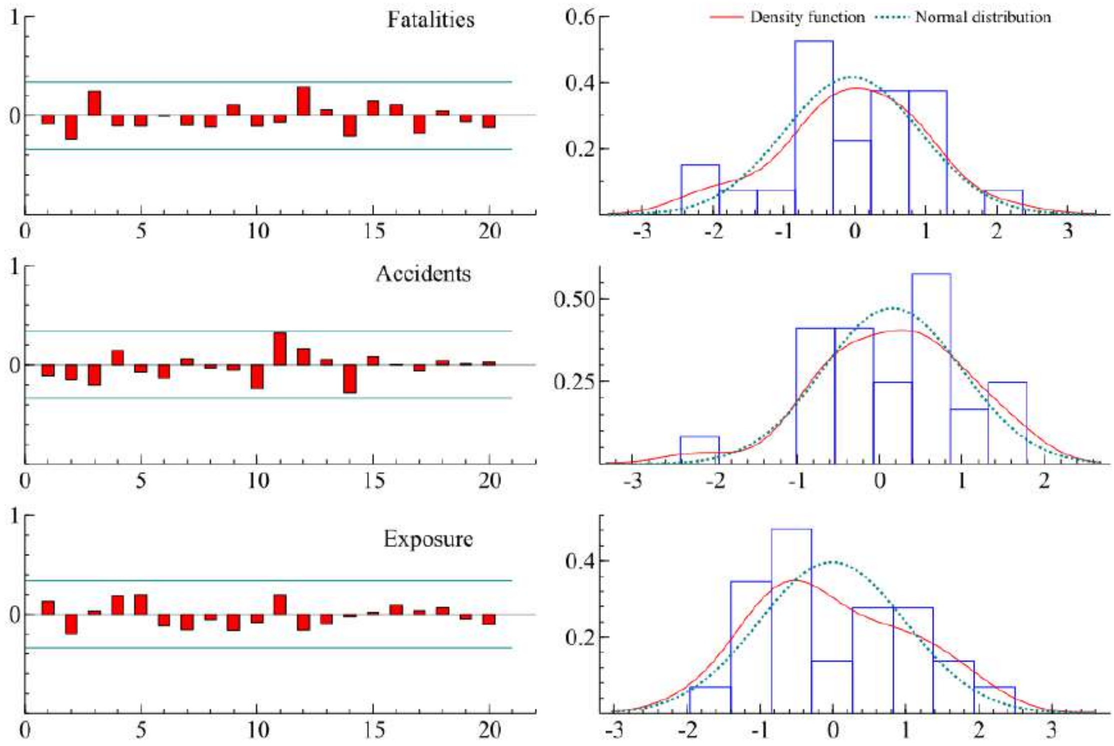

Figure 2. Autocorrelation functions and histograms of standardised residuals

The decomposition of unobserved components in Figure 3 shows that the regression line fits the data very closely (first row). The unobserved level component shows a gradual increasing trend of traffic fatalities in the study period (second row). Since the observed traffic fatalities decreased continuously over the same period, the impacts of policy interventions (and other exogenous factors) must increase substantially over time to not only compensate for the unobserved increasing trend but also result in declining traffic fatalities over time. The unobserved slope component confirms an overall unobserved increasing trend in traffic fatalities (i.e., positive slope) during the study period, with the exception of 1983 where slope was zero (third row). In addition, the slope estimates suggest that the rate of the unobserved increasing trend flattened in two periods: 1973-1983 and 1990-1995.

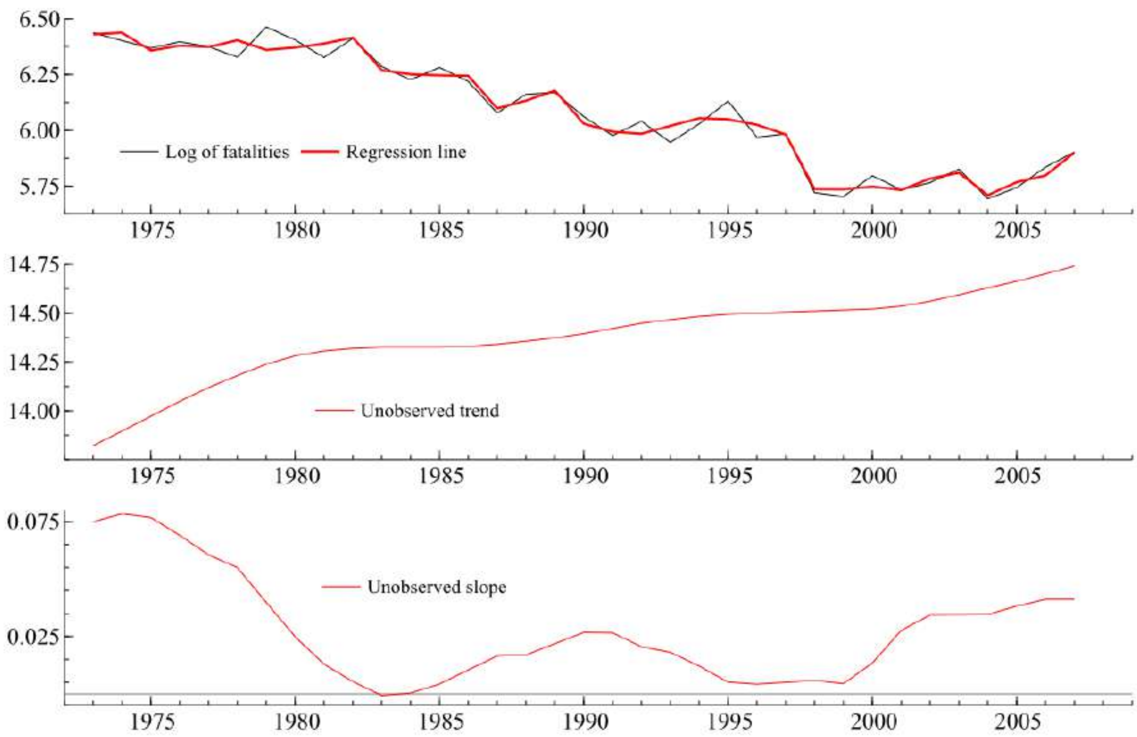

Figure 3. Unobserved components of traffic fatalities

The multivariate results in Table 1 (Multivariate 1) show that the unemployment rate and all policy interventions are statistically significant determinants of traffic fatalities in Queensland. In particular, the introduction of the random breath test program in 1988, the imposition of zero BAC for young drivers in 1991, the expansion of the random breath test program in 1998, and the "Safe4life" strategy in 2004 all led to reductions of traffic fatalities: by 12.1, 13.5, 22.8 and 15.3 per cent, respectively.[2] The results also suggest that a one per cent decrease in unemployment rate is associated with a 0.22 per cent reduction in traffic fatalities, on average. Notably, though, the frequency of accidents, GSP per capita and rainfall have no significant effects on traffic fatalities.

Table 1. Determinants of road traffic fatalities

Parameters	**Multivariate 1**	**Multivariate 2**	**Univariate**
Log of accidents	-0.083	***0.268	-0.065
Log of GSP per capita	-0.504	*-0.978	-0.644
Log of unemployment rate	***-0.221	***-0.225	**-0.162
Log of rainfall	-0.038	-0.011	-0.035
Random breath test program started (1=1988 onwards)	**-0.13	*-0.101	**-0.126
Zero BAC for young drivers (1=1991 onwards)	**-0.146	***-0.169	*-0.131
Random breath test expansion (1=1998 onwards)	***-0.259	***-0.223	***-0.296
"Safer4life" strategy (1=2004 onwards)	***-0.166	***-0.173	**-0.143

[2] As the regressions are in the log-log form, these numbers are calculated as $(e^{\beta}-1)\times 100$, where β is the parameters of the dummy variables for policy interventions.

Level variance (σ_ξ^2)	0.0003	.000002	0.001
Slope variance (σ_τ^2)	0.0002	0.0002	.00004
Irregular variance (σ_ϵ^2)	0.0017	0.002	0.002
Normality: test statistics (p-value)	1.47 (0.47)	1.41 (0.50)	0.03 (0.98)
Homoscedasticity: test statistics (p-value)	0.58 (0.77)	0.22 (0.98)	0.47 (0.84)
Akaike Information Criterion (AIC)	-5.47	-5.27	-5.14
R^2	0.80	0.76	0.72

*Note: Significant level: ***=1%; **=5% and *=10%. Covariance on unobserved components and parameters of other equations in multivariate models are not reported for brevity.*

The results also show a high correlation coefficient between the slope and level components of both the exposure and accidents series and the fatality series (see Table 2). This suggests that the level and slope of these series are affected by the same unobserved mechanism. To test this hypothesis, we re-estimated the model by imposing restrictions that the three equations follow a common trend and slope. The new results (Multivariate 2) show that the parameters of accidents become positive and statistically significant as expected. In particular, one per cent increase in accidents results in 0.27 per cent increase in traffic fatalities. Moreover, the parameter of GSP per capita is statistically significant at the ten percent level, suggesting that a one percent increase in GSP per capita is associated with 0.98 per cent reduction in traffic fatalities. The sign and magnitude of other parameters are similar the previous estimates. For example, the effects of random breath test, zero BAC and expansion of random breath test contribute to the reduction of traffic fatalities by 10, 17 and 22 per cent, respectively. The “Safe4life” strategy contributed to another 17 per cent reduction in traffic fatalities since its introduction in 2004. However, the introduction of the common trend and slope produce a slightly less desirable according to model selection criteria resulting in a lower R^2 and higher test statistic on the Akaike Information Criterion (AIC).

Table2. Covariance\correlation matrices of unobserved components

	Fatalities	**Accidents**	**Exposure**
Level			
Fatalities	0.0003	**0.6595**	**0.9519**
Accidents	*0.0005*	0.0021	**0.3975**
Exposure	*0.0003*	*0.0003*	0.0003
Slope			
Fatalities	0.0002	**-0.6963**	**0.9968**
Accidents	*-0.0002*	0.0005	**-0.7515**
Exposure	*0.0001*	*-0.0002*	0.0001

Note: Diagonal components are variances; lower-diagonal components are covariance (in italic); upper diagonal components are correlation coefficients (in bold)

For sensitivity analysis, we also present results of a univariate estimate (i.e., estimating Equation 1, only). These results suggest that the effect of the zero BAC policy is only statistically significant at the ten percent level, while the statistical significance of the unemployment rate and other policy interventions falls to the five percent level, with the exception of the random breath test expansion program (see Table 1, Univariate). In addition, both the R^2 and AIC confirm that the multivariate model is a superior choice to the univariate specification.

We acknowledge that, apart from controlling for drink driving, many other road safety initiatives were also implemented during the study period. Some of these we cannot take into account such as the compulsory seat belt wearing in vehicles started from 1973 as it covers the whole study period (i.e., so have no reference period to compare the effects of this initiative). Nevertheless, this issue has been investigated by Bhattacharyya and Layton (1979), who found that the seat belt law was associated with 46 per cent reduction in traffic fatalities in Queensland. Other interventions were introduced at the same periods that captured by the dummy variables in the analyses. For example, a policy to reduce impaired driving was introduced on the same period as the random breath test programs in 1988; the red light camera and random road watch programs were introduced on the same period as the zero BAC programs in 1991; and the Integrated Planning Act that aim for improve road design as implemented on the same period as the expansion of the random breath test program.

Conclusions

This paper has examined the effects of traffic safety interventions in Queensland in the 1973-2007 period, especially those target the drink driving behaviour using a state-space time series model that can control for unobserved components such as trend and slope. We found that the random breath test program, zero BAC policy for young drivers and random breath test expansion resulted in sizeable reductions in traffic fatalities, estimating their effects to be reductions of 10, 17 and 22 per cent, respectively. The "Safe4life" strategy in 2004 contributed to a substantial and statistically significant reduction in traffic fatalities of 17 percent. Among other exogenous factors, unemployment rates are the sole significant determinant of traffic fatality rates and the parameter estimates suggest a one percent increase in unemployment rate is associated with a 0.22 per cent reduction in traffic fatalities. These results suggest that policies that have targeted drink-driving as a way to combat road traffic casualties have proved very effective in this jurisdiction. In future work, it would be useful to subject these policies to a formal cost-benefit analysis, to determine if the resulting benefits outweighed the costs of implementing these policies. One of the difficulties of doing so is that detailed information on expenditures for such programs are likely to be difficult to obtain and, in particular, difficult to disaggregate by initiative. Nevertheless, work of the kind presented here could be used as the basis for such a study of the net welfare effects of these very effective policies.

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Enhancing South Australia's Graduated Licensing Scheme through road safety partnerships and a strong evidence-base

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Abstract

New rules to protect P-platers were introduced in South Australia on 28 July 2014. The changes are the most significant made to the Graduated Licensing Scheme in this State, applying both peer-passenger and night-time driving restrictions to P1 drivers and extending the time on a provisional licence from two to three years.

The reforms represent almost three years of work, including a major public consultation process, the drafting of legislation and passage of the Bill through Parliament. An inter-agency project group was responsible for successfully implementing the changes.

While reforms of this nature are never easy, the consultation process at each milestone was critical to success. It concentrated on the fact that the proposed reforms reflect international best practice, are evidence-based and that individual components were already in place in other parts of the country.

In addition, an extensive crash analysis was undertaken to work out the casualty savings if the laws had been in place during the previous five years, presenting a compelling case to Parliamentary members and the community. Much work was done to ensure these initiatives had the backing of major stakeholders, many of whom were strong advocates for the new laws throughout the process.

This partnership approach, together with sound evidence and a commitment to bringing the community along with us has meant a relatively smooth and successful implementation of these reforms. Most importantly, this achievement will have real and long lasting benefits for young South Australian drivers, their parents and the wider community.

Introduction

Despite significant reductions in South Australia's road toll over the past decade, young drivers have continued to be over-represented in road deaths and serious injuries, much more so than older drivers. In South Australia, young people aged 16 to 24 make up 12% of our population; however, they account for 22% of road deaths and 24% of serious injuries (South Australian Road Crash Database, 2009-2013).

Similar to other jurisdictions both interstate and overseas, South Australia manages the risks to young drivers through a graduated licensing scheme (GLS). The GLS allows novice drivers to gradually acquire safe driving experience with supervisory influences and restrictions progressively lifted as drivers progress through the stages of holding a learner's permit, following by a provisional (P1 and P2) licence and finally graduate to a full (unrestricted) licence.

South Australia has been working diligently to improve the safety outcomes for young drivers in this State over the past 10 years. Following the introduction of minimum supervised driving hours requirements for learner drivers, provisional P1 and P2 stages and the Hazard Perception Test in 2005; mobile phone restrictions for learner and P1 drivers in 2009; the GLS in South Australia was last amended in 2010. Of most significance was the increase in the minimum time required on a learner's permit from six to 12 months for drivers aged under 25 years as well as an increase in the minimum supervised driving time for learner's permit holders from 50 hours (including 10 at night) to 75 hours (including 15 at night).

While South Australia's GLS had been significantly improved over the years, the launch of *South Australia's Road Safety Strategy 2020 – Towards Zero Together* (Government of South Australia, 2011) placed a high priority and renewed focus on considering further measures to reduce the number of road deaths and serious casualties for young South Australians.

At the time, South Australia had the second worst fatality rate per population for 16-19 year olds of all Australian states and territories. Those jurisdictions that were ahead of South Australia such as Victoria, New South Wales, Queensland and Western Australia had already enhanced their graduated licensing schemes to reflect a number of 'best practice' findings.

International research evidence and comparisons with schemes in other Australian jurisdictions indicated that peer passenger restrictions, night driving restrictions, increasing the time on a provisional licence and raising the minimum age for a provisional licence all warranted further consideration.

Discussion

Consultation Process

On 14 October 2011, the South Australian Government released *South Australia's Graduated Licensing Scheme - Initiatives to Protect Young Drivers Discussion Paper* (Government of South Australia, 2011). The initiatives proposed in the Discussion Paper included:

1. A passenger restriction for all P1 drivers allowing no more than one passenger under 21 for the duration of P1 (with exemptions for immediate family members or for employment, or if a Qualified Supervising Driver (QSD) is present).
2. A restriction on driving between midnight and 5am for all P1 drivers for the duration of P1 (with exemptions for work-related driving or if a QSD is present).
3. Raising the minimum age for a provisional licence from 17 to 18 years.
4. Extending the total minimum provisional licence period from two to three years.
5. Removing regression to a previous licence stage following a disqualification period.

The Discussion Paper presented the community with factual information showing the need to further protect young drivers, particularly in rural areas of the State. Supporting evidence that the initiatives being proposed were in line with international best practice, were proven to work and that individual components were already in place in other parts of the country was also provided. It indicated that for some of the proposals exemptions would be considered for employment and possibly for other purposes, although the detail of the proposed exemption scheme had not yet been determined.

Importantly, the Discussion Paper also included the expected reductions in young driver fatalities and serious injuries for each initiative based on modelling done by the Centre for Automotive Safety Research (CASR). The estimated crash reduction for each initiative was a powerful tool to promote open discussion with the community over the value of adopting such measures in South Australia and was very appealing to the media.

The consultation process ran for an eight week period until 8 December 2011. The proposed initiatives generated significant interest and public debate, and 1079 responses were received from people of all ages across the state. In addition to members of the public, responses were submitted from a variety of road safety stakeholders including those representing motorists, the health sector and youth interests, Members of Parliament, local government and community road safety groups.

A detailed report on the public consultation outcomes (Government of South Australia, 2012), including the views expressed by key stakeholders, was released in August 2012. It showed the level of support or non-support for each initiative, and also where responses were not clearly either supportive or non-supportive (see Table 1).

Table 1: Level of support by respondents for each GLS initiative

Initiative	Supportive	Non-supportive	Not clearly supportive or non-supportive
Passenger restriction	38%	45%	16%
Night-time driving restriction	39%	40%	21%
Raising the minimum licensing age from 17 to 18 years	20%	67%	13%
Extending provisional licence from 2 to 3 years	35%	36%	29%
Removing regression	42%	33%	23%

Analysis was undertaken according to the age, gender, licence type, location and parental status of the respondents. Not surprisingly given young people were most likely to be affected by the changes, there was not support by people aged under 25 for the proposed night driving and passenger restrictions, whereas they received general support from older age groups. The proposal to raise the provisional licensing age to 18 received the least support, despite evidence that it would bring the greatest trauma reductions for South Australia. Due to the strong community feedback, the South Australian Government decided not to proceed with this initiative.

Many respondents cited concern about the possible impact of raising the licensing age to 18 on young workers and students, particularly those living in rural and regional areas who have limited access to public transport. There was also a belief that the proposal would delay the crash statistics to a higher age bracket, despite the information being provided that the first year crash rate of new P1 drivers aged 18 would not be expected to be as high as that for 16 or 17 year olds.

Some respondents were concerned that the proposed initiatives would “punish the majority for the mistakes of a few,” indicating a belief that the young driver crash rate could be attributed to risk taking by a small number of drivers. Responses on the proposed passenger restriction included concern about the possible impact on car-pooling and designated driver programs where one person in a group of friends agrees to not drink alcohol. Another common concern was the possible effect on regional people who rely on others when travelling to work, school, sport or other social functions. Similar concerns were expressed about the proposed night driving restriction, and some respondents requested more detail about the exemption scheme.

There were also respondents, including parents and young people, who supported the proposed restrictions on the basis that they would reduce the peer pressure on young people to drive late at night or with passengers and assist parents to enforce a curfew or reduce worry about them driving unsafely if encouraged to do so by others. Many respondents who supported the restrictions tended to simply indicate their support, although some said they agreed the changes were likely to reduce the youth road toll.

The proposed initiatives were supported by the Royal Automobile Association (RAA), the Motor Accident Commission, CASR, South Australia Police (SAPOL), emergency services and the health sector. Throughout the process of developing the GLS changes, these key stakeholders had an important role advocating for the proposals. All worked cooperatively to ensure that consistent messages were imparted to the community, helping to achieve increased awareness, understanding and support for the proposals.

After work had begun on drafting the new legislation, the Department of Planning, Transport and Infrastructure (DPTI) offered briefings to organisations that had either expressed concern or requested further information during the initial consultation phase. They were provided with a detailed briefing on the proposed changes, including how the proposed exemption model would work and what it would mean for their members, as well as for young drivers. These briefings, along with those that followed with Members of Parliament, were particularly important in gaining support for the Bill. The majority of organisations who received a briefing and were presented with the evidence supported the changes going forward, and assisted with disseminating information about the new laws after they were passed by Parliament. The Youth Affairs Council of South Australia did not support the GLS initiatives on the basis that they would impact on young people’s mobility.

Evidence-Based Approach

There was strong evidence to support the introduction of passenger and night driving restrictions for young P1 drivers, and it was important to convey this to people in a way that could be easily understood. A variety of visual aids were used to explain the information, ranging from a simple flyer through to detailed graphs and tables.

While the visual aids were refined over time, the key facts presented were the same in the Discussion Paper right through to the final communication strategy leading up to implementation, almost three years later. The data sets shown below, which were updated as time progressed, were key to getting the GLS initiatives through Parliament and implemented in South Australia.

<u>Age and Population Representation</u>

People aged 16 to 24 years are over-represented in serious casualties in South Australia. For the years 2009-2013 they made up 12% of the population, but accounted for 22% of all fatalities and 24% of all serious injuries as shown in Figure 1 (South Australian Road Crash Database, 2009-2013).

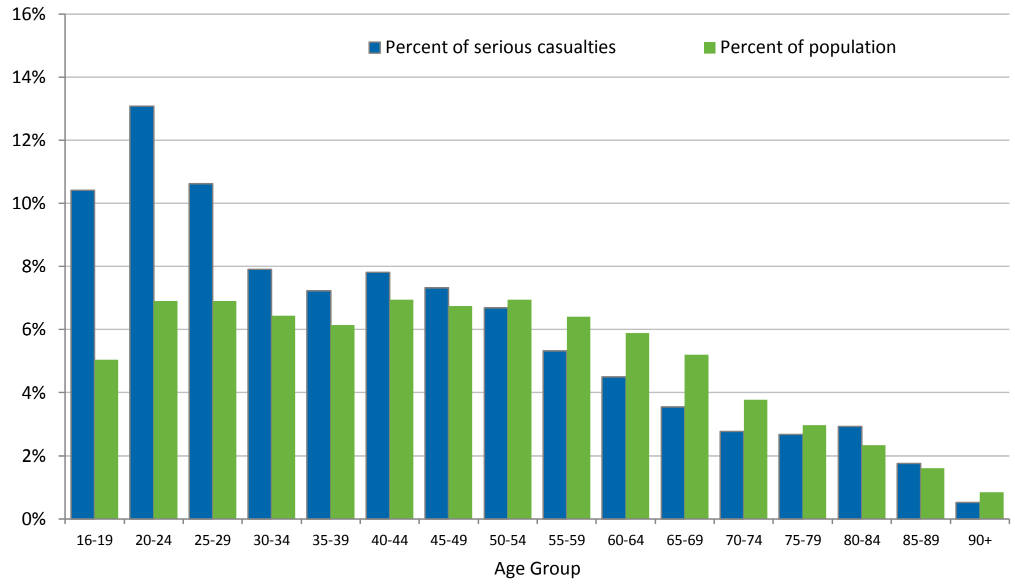

Figure 1: Fatal and Serious Casualties by age and population distribution, South Australia, 2009 - 2013

<u>Need to protect P-Platers</u>

Young drivers are more likely to crash in the first twelve months of holding a provisional licence, when the driver is least experienced and driving unsupervised. Figure 2 shows that upon gaining a provisional licence and beginning to drive unsupervised, the percentage of young drivers involved in crashes rises eleven times (Austroads, 2008).

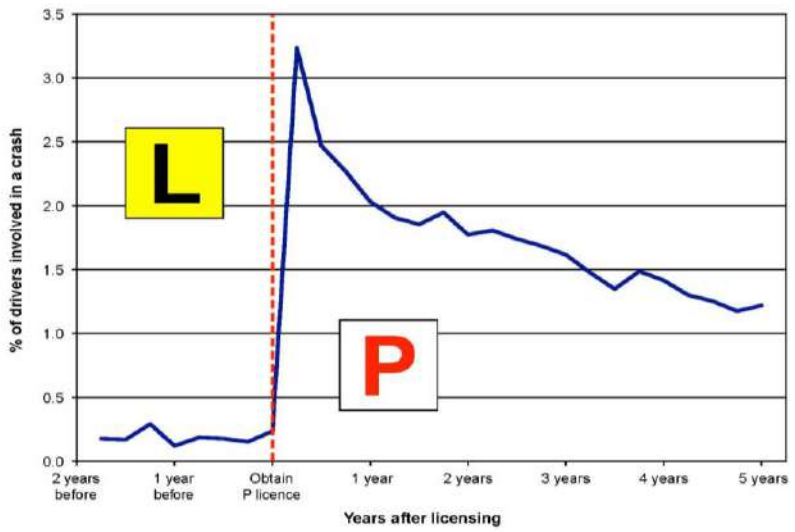

Figure 2: Percentage of drivers involved in a crash five years after licensing

<u>Interstate Comparison</u>

Until recently, South Australia has had the second worst fatality rate per population for 16-19 year olds of all Australian states and territories. While 2009-2013 figures show South Australia has moved up to be ahead of the Northern Territory and Tasmania, the Government's goal is for South Australia to have the lowest fatality rate per population for 16 -19 year olds in the country. The information in Table 2 clearly demonstrated that there was more that could be done in South Australia to improve the safety of young drivers (Bureau of Infrastructure, Transport and Regional Economics, 2013).

Table 2: 16 – 19 year old fatalities per 100,000 population by jurisdiction

State	Fatalities 2008-12 Avg	Fatality Rate
ACT	1	5.0
Vic	28	9.7
NSW	36	9.8
Qld	31	12.6
WA	18	14.4
Tas	4	14.0
SA	**14**	**16.0**
NT	4	32.1
Aust	136	11.6

State	Fatalities 2009-13 Avg	Fatality Rate
ACT	1	4.1
Vic	25	8.7
NSW	35	9.4
Qld	29	11.6
WA	15	12.0
SA	**11**	**12.8**
Tas	4	14.8
NT	2	18.4
Aust	122	10.3

Regional Vs Metropolitan Drivers/Riders

The information that young rural drivers were two and half times as likely to die or be injured in a crash than their peers in metropolitan Adelaide is seen in Figure 3 (South Australian Road Crash Database, 2009-2013). This was confronting information for many rural stakeholders who had not realised that young rural drivers were at much greater risk of dying or being seriously injured in a crash. It also showed that young rural drivers could receive a disproportionate safety benefit from the proposed initiatives, which was crucial in gaining support when they were also less likely to have access to public transport options than young people in the city.

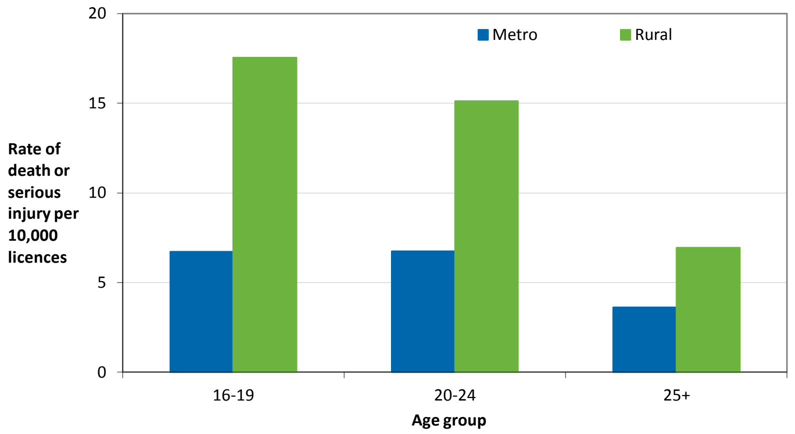

Figure 3: Rate of death or serious injury per 100,000 licences held for drivers/riders by residence, South Australia, 2009-2013

Night Driving Restriction

Figure 4 shows the over-representation of young drivers in fatal crashes between 10pm and 5am as a percentage of total crashes in South Australia between 2009 and 2013. Of the 16-19 year old drivers/riders involved in a fatal crash, 30% crashed between the hours of 10pm and 5am. This compared to 12% for drivers/riders involved in fatal crashes aged 25 years or over (South Australian Road Crash Database, 2009-2013).

Figure 5 also shows that P1 licence holders involved in fatal and serious injury crashes are more prevalent at night than holders of a full licence.

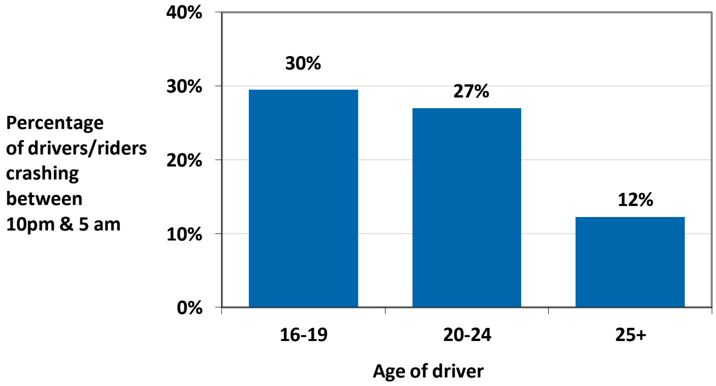

Figure 4: Drivers/riders involved in fatal crashes between 10 pm and 5 am as a percent of total crashes, South Australia, 2009-2013

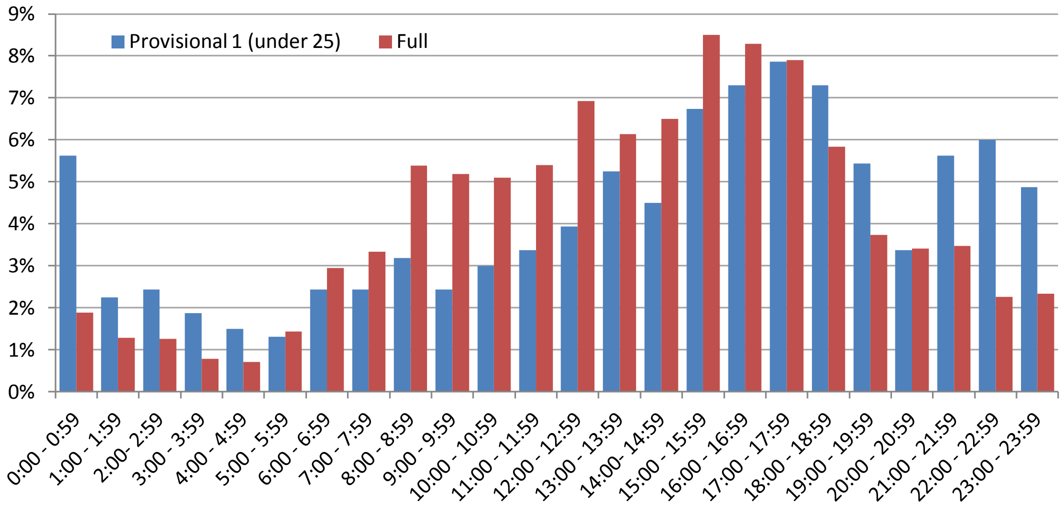

Figure 5: P1 and Full licence holders involved in fatal and serious injury crashes by time of day, South Australia, 2009 – 2013

Passenger Restriction

Figure 6 shows the over-representation of young drivers in fatal crashes involving two or more passengers as a percentage of total crashes in South Australia between 2009 and 2013. In this case, 25% of 16 – 19 year old drivers involved in fatal crashes are carrying two or more passengers. This compared to 12% of drivers involved in fatal crashes over the age of 25 carrying two or more passengers (South Australian Road Crash Database, 2009-2013).

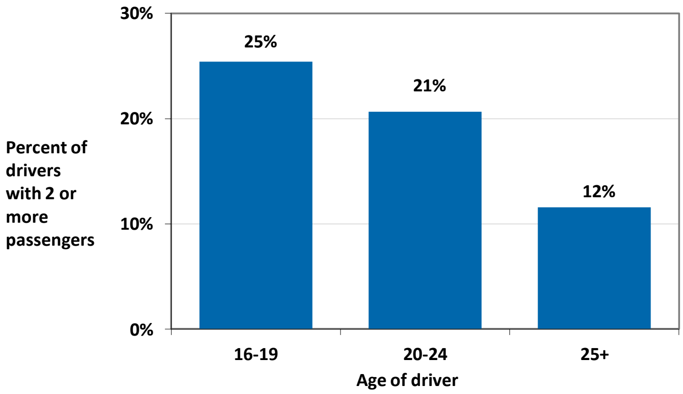

Figure 6: Drivers involved in fatal crashes with 2 or more passengers as a percent of total drivers, South Australia, 2009-2013

Crash Analysis

DPTI undertook an extensive crash analysis to provide further evidence that the proposed changes could save lives and prevent serious injuries (Noack et al, 2013). The analysis examined individual crashes of all P1 licence holders aged 16-24 that were involved in casualty crashes between 2008 and 2012. All casualty crashes that fell into one of the proposed restrictions were considered, the ages of injured passengers were determined where possible, as was the time of the crash. The casualties that resulted from these crashes were then calculated. From this analysis it was found that the overall total number of fatalities and injuries that had the potential to be prevented if these restrictions were in place in 2008 was:

- 22 fatalities (an average of 4 per year)
- 240 serious injuries (an average of 48 per year)
- 1397 minor injuries (an average of 279 per year)

The Department's analysis, along with existing key statistics provided during the consultation process, was used to provide the community with a real understanding of the lives that could potentially be affected as a way to communicate the safety benefits of the proposals. Presenting the statistics in an interesting and easy to read format that has an impact on young people, their parents, the business sector and parliamentarians has been crucial to obtaining support for the GLS changes (see Figure 7). It was also another opportunity to present a united front between key road safety stakeholders in support of the proposals.

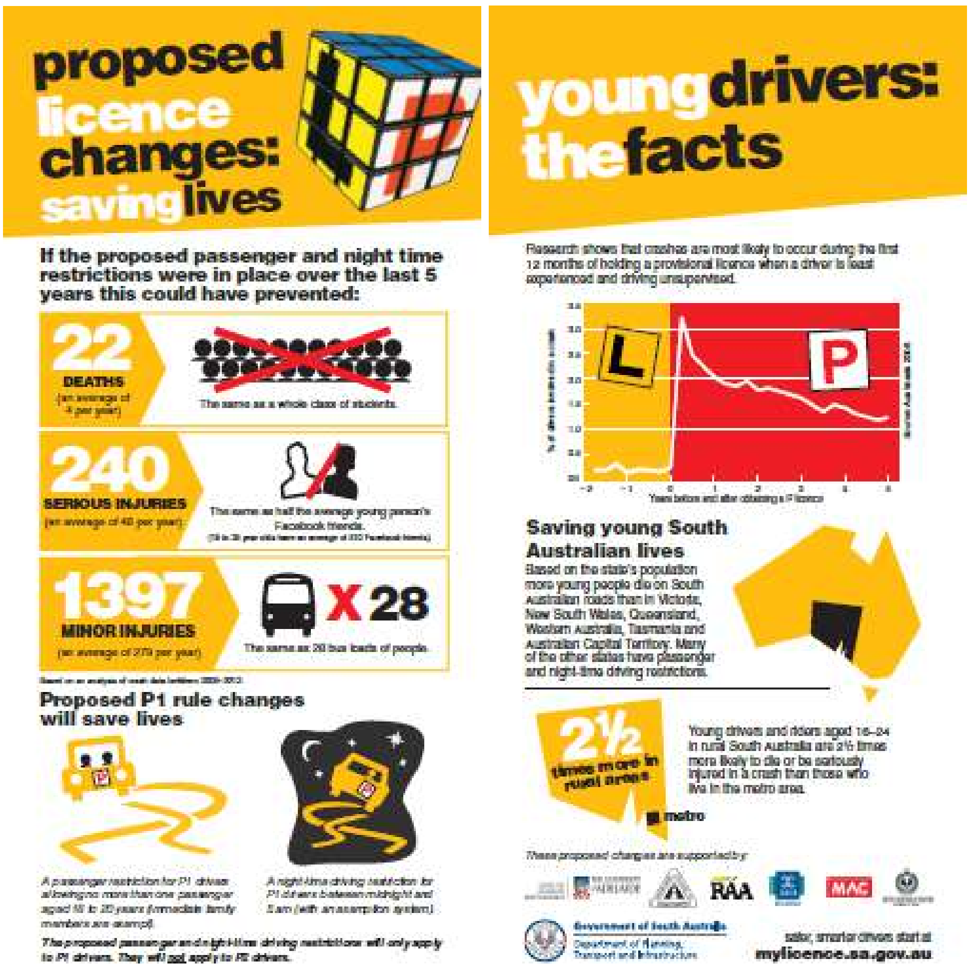

Figure 7: An example of one of the many GLS Brochures

Exemption Scheme

The exemption scheme was a key factor in gaining support for the changes. The final scheme allows young drivers to drive between midnight and 5am to participate in employment, education and training, as well as sporting, artistic, charitable, religious, scientific and volunteer commitments, addressing significant community concern that young drivers should not be seriously disadvantaged by the new laws, particularly in rural areas where there are limited public transport options. Drivers are able to carry more than one peer passenger if they are driving for employment purposes or driving on duty as an emergency services worker.

Driving to participate in a sporting activity was included after feedback was received from the community that young people may need to drive to attend swimming or rowing training prior to 5am. The activity must be provided by an organisation, association or club, and driving during the restricted hours to watch a sporting event is not allowed.

Following amendments to the Bill while it was in Parliament, the exemption grounds for the night driving restriction were expanded to include driving to participate in artistic, charitable, religious and scientific activities provided by an organisation, association or club.

Considerable thought was given to selecting an exemption model, particularly as large numbers of people would potentially be seeking an exemption. DPTI worked closely with SAPOL to develop a workable proposal. The model that was chosen was based on the approach taken in Western Australia, where an automatic exemption from the night driving restriction is available for employment or education/training purposes. The model places the onus on the driver to satisfy police at the roadside that they are driving under one of the exemption grounds. It caters to the needs of young people who may frequently change the circumstances of their employment, and often at short notice. It was decided that a formal application process where each application must be individually assessed against the relevant criteria may result in delays for drivers who urgently needed an exemption.

It is recommended that drivers carry evidence that they meet the exemption criteria while driving, for example a letter from their employer, education or training institution; or sports club or association. To assist drivers, a voluntary P1 Driver Exemption Form was developed in conjunction with SAPOL and made available on www.mylicence.com.au. The form contains the recommended information for young drivers to complete.

Implementation and Communication Strategy

Citing the evidence behind the restrictions strongly assisted with getting the message through about the safety benefits for young drivers. It was also very important that key messages were developed and communicated throughout the process, and this helped to dispel some of the myths that exist about young drivers, for instance that the crash statistics are the result of extreme behaviour by only a few drivers. It was also important to let people know that the initiatives were already in place in other jurisdictions and that they were shown to work.

The following are examples of the key messages that were used:

- Despite steady falls in South Australia’s road toll over the past decade, young drivers continue to be over-represented in road trauma statistics compared to older age groups.

- Crashes are most likely to occur during the first 12 months of holding a provisional licence when the driver is least experienced and driving unsupervised.

- Young drivers in rural South Australia are two and a half times more likely to die or be injured in a crash than their peers in metropolitan Adelaide.

- South Australia has the second worst fatality rate for this age group of all Australian states and territories – almost double that of Victoria, New South Wales and Queensland.

- The initiatives reflect international best practice, are evidence-based and are already in place in other parts of the country.

- The initiatives are not about making life tougher for young drivers. They're about protecting them and will result in fewer deaths and injuries among young drivers, their passengers and other road users in South Australia.

Upon passage of the Bill, a significant communications campaign was prepared to accompany the new laws. This was the final stage in the commitment to bringing to the community along with us to achieve a relatively smooth and successful implementation of the reforms, and it was important to convey both the detail of the changes and the reasons behind the new restrictions.

A state-wide advertising campaign involved press, radio, digital and bus shelter advertising. In addition, a letter and an information brochure were sent to all Learner's Permit and P1 drivers across the State (approximately 100,000). Some 500 letters were also sent to employer and volunteer groups, education/training institutions and relevant clubs and associations to advise them of the detail of the changes, how the exemption model would work and what it would mean for them. These organisations were encouraged to assist young drivers by recognising that the restrictions exist to reduce the risk of a serious injury or fatality and if asked, to provide a letter or sign a form as evidence of their need to travel. A specific page on the mylicence website was also dedicated to the new laws. More information is available at http://mylicence.sa.gov.au/gls/home.

The GLS changes were successfully implemented by an inter-agency project group including representatives from DPTI, Service SA, SAPOL and the Courts Administration Authority. This group was established following passage of the Bill through Parliament, and it required a six month period to ensure that the changes were successfully implemented.

The GLS changes introduced on 28 July 2014 include:

Passenger restriction

P1 licence holders aged under 25 must not carry more than one passenger aged between 16 and 20 (excluding immediate family members) unless they have a qualified supervising driver sitting beside them or they meet one of the exemption criteria below:

- driving in the course of employment; or
- a police or emergency services officer on duty.

Night driving restriction

P1 licence holders aged under 25 must not drive between midnight and 5am, unless they have a qualified supervising driver sitting beside them or they meet one of the exemption criteria below:

- driving between home and work or driving in the course of employment;

- driving between home and education/training or driving in the course of education/training with a school, university, TAFE, apprenticeship or other formal training provider;
- driving between home and formal volunteer work or driving in the course of performing formal volunteer work;
- driving between home and an activity to participate in sports, artistic, charitable, religious or scientific activities; or
- a police or emergency services officer on duty.

Learner motorcyclists under the age of 25 without a P2 or full licence for a car are also subject to the night driving restriction.

Extending the total minimum provisional licence period from two to three years

The total length of time a new driver must hold a provisional licence was extended from two years to three. This means one year on a P1 licence and two years on a P2 licence. This in turn would extend the duration of conditions such as the zero blood alcohol limit, speed and high power car restrictions and a lower demerit allowance. Extending these conditions will help to keep our young drivers out of high-risk situations without impinging on their mobility.

Removing regression to a previous licence stage following a disqualification period

Regression to a previous licence stage has been removed. This will mean that disqualified L and P drivers will return to the licence stage they were at when they committed the offence resulting in the disqualification.

The Hazard Perception Test (HPT) being a requirement from L to P1, rather than P1 to P2

The Hazard Perception Test has become a requirement to progress from L to P1 rather than P1 to P2.

Throughout this process, the GLS initiatives have generated significant community interest and public debate. However, once the new laws had passed Parliament and the community were advised that they were coming into effect in July 2014 the comments received from the public generally moved from “these initiatives are unfair/not workable” to “how will these new laws affect me personally” with many parents and young drivers enquiring about their own situation and how the exemption criteria might apply. Once the laws had come into effect, the enquiries subsided significantly supporting the notion that the community was now aware of the new laws and had come to accept them. The evaluation of the communications campaign also showed a high level of community awareness about the new laws.

Interim Results

In South Australia, while young people are over-represented in fatalities and serious injuries, crash data shows that in the last five years the number of young lives lost has decreased. In the 11 month period until 1 July 2015 there have been five P1 drivers/riders under 25 years of age involved in fatal crashes compared to an average of 11 per year for the years 2009-2013.

In the nine month period until 1 May 2015, preliminary figures show that 42 P1 drivers/riders aged under 25 were involved in serious injury crashes and 402 in minor injury crashes. On average (for the years 2009-2013) 96 P1 drivers/riders aged under 25 were involved in serious injury crashes and 869 in minor injury crashes per year. An independent formal evaluation on the GLS changes will be undertaken once sufficient crash data is available.

Conclusion

Improving young driver safety has been an emerging priority for South Australia over the last decade. While continuing to push for more significant reforms over the longer term, our strategy has been to accept smaller safety improvements thereby enhancing the GLS in this State incrementally over time. This has required constant review and evaluation of the evidence so as to be able to persuade the Government and the community of the changes needed to further protect young South Australians.

The new rules for young Provisional (P1) licence holders represent almost three years of work including a major public consultation process, the drafting of legislation and passage of the Bill through Parliament at the end of 2013, followed by a six month implementation period which included a significant public communication campaign. In around five years' time when there is sufficient crash data, an independent formal evaluation on the GLS changes will be undertaken.

These latest reforms are the most significant changes made to the GLS in South Australia, and this package means that we now have one of the best GLS in the country. The new laws have now been in place for 11 months and with no significant issues reported in that time, there is a level of confidence that the laws have been accepted by the community and are working well.

This result would not have been achieved without the combined effort of road safety stakeholders who worked together to develop and implement changes that will be of lasting benefit to young people in South Australia. Crucial support was also gained by providing the evidence for change in a variety of ways, so that the community and key stakeholders understood the road safety risks facing younger drivers, the reasons for the changes, and the evidence that the restrictions could save lives.

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The effect of the 100% Motorcycle Helmet Use campaign on motorcyclist head injuries in Thailand

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Abstract

In 2011, the Thai government introduced the 100% Motorcycle Helmet Use campaign in an effort to increase helmet wearing among motorcyclists. A nationwide mass media campaign (television, radio, internet, and social media) provided information on the advantages of helmet wearing, disadvantages of non-helmet wearing, instructions for proper helmet usage and choosing a good quality helmet. The aim of this study was to assess the impact of this campaign on motorcycle head injury. Motorcycle injury data was extracted from twenty-seven hospitals that voluntarily participate in the Thai Injury Surveillance (IS) system for years 2009-2012 and helmet use estimates were taken from roadside surveys. Helmet use among motorcyclists changed very little with the onset of the helmet use campaign; however, motorcyclists wearing helmets were associated with a 52% reduction in the odds of a head injury (OR=0.48, 95% CI: 0.47-0.49). The immediate impact of the campaign on head injury rates was assessed for each hospital using an interrupted time series generalized linear autoregressive moving average (GLARMA) model. The results from each hospital were synthesized using a meta-analytic approach. We estimated no significant reduction in motorcycle head injuries (IRR=0.99, 95% CI: 0.92-1.06) following the onset of the helmet use campaign; however, the results by hospital were highly heterogeneous ($I^2 = 65\%$). There is little evidence to suggest the helmet use campaign had any causal impact on motorcycle-related head injury during this period, although helmet use was associated with a significant reduction in head injury.

Introduction

Road traffic injuries are considered one of the leading causes of death internationally, most of which occur in low and middle income countries (WHO, 2013). Thailand is a developing country in South-East Asia with a high rate of road-crash death and injury compared to similar countries (WHO, 2009). For the period 2005-2010 in Thailand, motorcyclists comprised 80% of traffic injuries, with 43% of these being head injuries (Bureau of Epidemiology, 2013). During this period, about 8% of non-helmet wearing motorcyclists had severe brain injury (Glasgow Coma Scale 3-8), compared to only 3% among those motorcyclists wearing helmets.

It is believed that motorcycle helmets protect the motorcyclist's head during impact, thus preventing or reducing head injury (Liu et al., 2004). To increase helmet usage, the Thai Helmet Act was enacted (Bangkok, April 1995; Thailand, January 1996). Initial compliance was high in Bangkok; however, wearing rates declined sharply thereafter with low compliance outside Bangkok.

To increase helmet usage, the 100% Motorcycle Helmet Use campaign was launched nationwide on 4 January 2011 (Royal Thai Government, 2010). Information on the advantages of helmet wearing, disadvantages of non-helmet wearing, instructions for proper helmet usage and choosing a good quality helmet was promoted nationwide through mass media advertisements (television, radio, internet and social media), stickers, and pamphlets (ThaiRoads Foundation, 2013). Additionally, there were fund raising campaigns to provide free or discounted helmets to students and poor people, and government officials were instructed to comply with the helmet law. In some provinces, such as Rayong, Nakhon Pathom and Nakhon Sawan, motorcyclists charged without wearing a helmet were given a free helmet.

The impact of the campaign on motorcycle related head injury is unknown. The objective of this study was to evaluate the impact of the 100% Motorcycle Helmet Use campaign on motorcyclist head injuries in Thailand using injury surveillance data from twenty-seven hospitals and roadside surveys of helmet wearing. In particular, we are interested in assessing (1) whether the introduction of the campaign was associated with an increase in motorcycle helmet wearing, (2) whether there was a negative association between helmet wearing and head injury, and (3) whether the introduction of the campaign was associated with a decrease in head injury.

Methodology

Motorcycle-related hospitalisations were extracted from twenty-seven hospitals that voluntarily participate in the Thai Injury Surveillance (IS) data system for the period 2009-2012. Motorcycle head injuries were identified as emergency room presentations with external cause of injury (motorcycle driver or occupant) and diagnoses in the International Classification of Disease 10th Revision (ICD-10) range S00-S09. The IS system includes fatalities (before or after arrival to ER), cases observed and/or admitted to hospital. Helmet use was also recorded in the IS data system. This data were then aggregated by month for time series analysis. Monthly population estimates were interpolated from published yearly estimates for the provinces in which the twenty-seven hospitals are located (Bureau of Registration Administration, 2014).

The period 2009-2012 was chosen as there was a substantial number of participating hospitals in the IS data system during that period and partially corresponds with a nationwide roadside survey of motorcycle helmet wearing. The survey began in 2010 and was conducted yearly in urban and rural areas of each Thai province using stratified sampling methodology (ThaiRoads Foundation, 2014).

Statistical methods

The impact of the campaign on motorcycle-related head injuries was assessed using an interrupted time series generalized linear autoregressive moving average (GLARMA) model with monthly population estimates as an offset (Davis, Dunsmuir & Streett, 2003). The basic model has the following form:

$$log(\mu_t) = \beta_0 + \beta_1 Time_t + \beta_2 Campaign_t + \beta_3 Time_t \times Campaign_t + log(population) + Z_t.$$

The parameter β_0 estimates the level of motorcycle head injuries immediately prior to the campaign, β_1 estimates the pre-campaign trend, β_2 estimates the log incidence rate ratio (IRR) of motorcycle head injuries immediately after the introduction of the campaign, β_3 estimates the change in the trend after the campaign, and Z_t is an autoregressive moving average process used to account for possible serial correlation.

Estimates of the immediate effect of the campaign, i.e., β_2, from each hospital were combined into an overall estimate through a random effects meta-analysis. The extent of heterogeneity was assessed by the I^2 statistic (Higgins et al., 2003).

Results

There were 109,709 head injury cases for time series analysis. The monthly average number of motorcycle related head injuries across all hospitals was 2396.4 and 2174.7 before and after the onset of the campaign respectively. Males were over-represented among head injury cases (73.1%) and the average age was 31.9 years.

Following the onset of the campaign, helmet wearing increased slightly across the seventeen provinces, was unchanged in four provinces and decreased in five provinces. Overall, the motorcycle helmet wearing rate in Thailand increased slightly from 44% in 2010 to 46% in 2011 after the onset of the campaign (Jiwattanakulpaisarn, 2012).

Motorcycle helmet use was associated with a 52% reduction in the odds of a head injury before and after the onset of the helmet use campaign (OR=0.48, 95% CI: 0.47-0.49). Additionally, the helmet wearing rate of head injury hospitalisations was lower than the helmet wearing rate estimates of the general population.

Immediately following the introduction of the campaign, there was very little change in motorcycle head injuries across all hospitals (IRR=0.99, 95% CI: 0.92-1.06, $I^2 = 65\%$). Motorcycle head injury significantly decreased for 3 hospitals, yet also significantly increases for another 4 hospitals (see Figure 1).

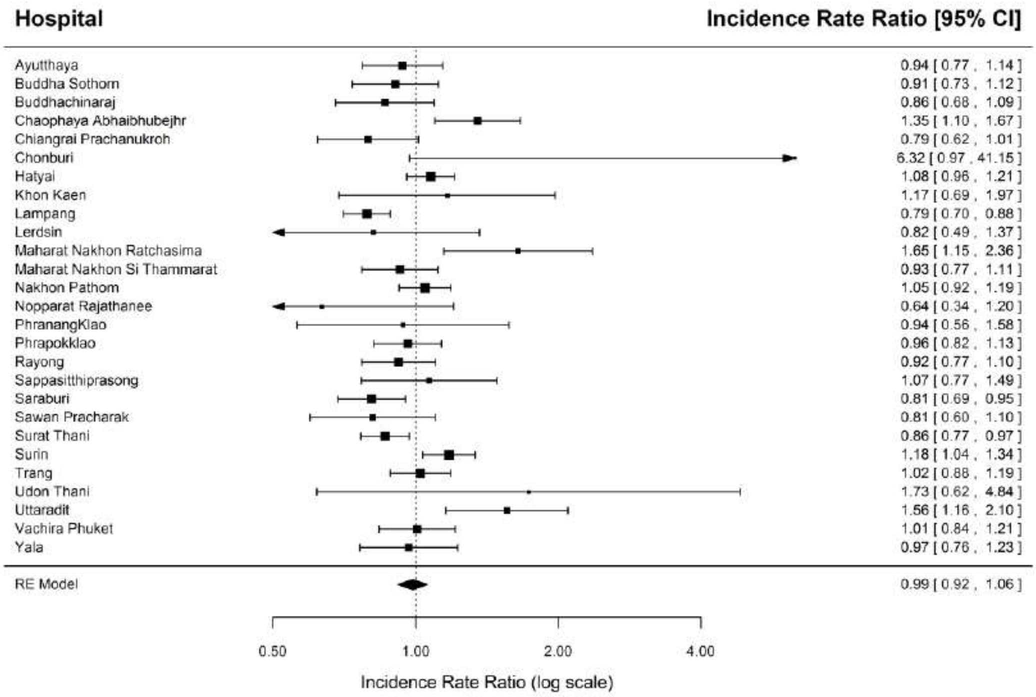

Figure 1. Immediate effect of 100% Motorcycle Helmet Use campaign on motorcycle head injury for 27 hospitals in Thailand

Discussion

Our results were mixed with regards to the impact of the Thai 100% Helmet Use campaign. Motorcycle helmet wearing changed very little and it was therefore expected that post-campaign motorcycle head injury rates would be similar to the pre-campaign rates, although these results were highly heterogeneous across hospitals.

We also found helmet use was associated with a 52% reduction in the odds of a head injury (OR=0.48, 95% CI: 0.47-0.49) for motorcyclists presenting to the hospitals included in our study. Our results also suggest unhelmeted motorcyclists are over-represented in the hospital record. When taken as a whole, our results support the promotion of motorcycle helmet wearing and, therefore, more effective strategies to increase helmet wearing should be explored.

The limitations of this study relate to the use of administrative data sets, possible poor coverage of Thai hospitals (27 out of 1,318) and rates were computed using province level population estimates although some patients may reside in another province. These limitations are possibly attenuated as the Thai Injury Surveillance system is routinely checked using data error software and site audits are performed; random effects meta-regression treats results from each hospital as a random sample of all hospitals; and a sensitivity analysis using only patients who reside in each hospital's province did not change the results appreciably.

Conclusion

In this study, we investigated the effect of the 100% Motorcycle Helmet Use campaign on motorcycle related head injuries in Thailand. We estimate no immediate reduction in head injuries. However, we did find helmet wearing motorcyclists presenting to hospital had a reduction in the odds of a head injury and unhelmeted motorcyclists were over-represented in the hospital record. Our overall results support the use of motorcycle helmets and suggest research into alternative strategies to increase helmet usage.

Acknowledgements

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Developing a new index for comparing road safety maturity: Case study of the ASEAN Community

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Abstract

As part of the development of the ASEAN Regional Road Safety Strategy, a new index for measuring road safety maturity (RSM) was constructed from numerical weightings given to measurable factors presented for each of the pillars that guide national road safety plans and activities in WHO Global Road Safety Report 2013: road safety management, safer road and mobility, safer vehicles, safer road users and post-crash response. The index is based on both a content analysis approach and a binary methodology (report/no report) including measures which have been considered pertinent and not redundant. For instance, the use of random breath testing and/or police checkpoints in the national drink driving law are combined in the enforcement index. The value of the index per pillar ranges from 0 to 100%, taking into account whether there is total, partial or non-implementation of certain actions. In addition, when possible, the self-rated level of enforcement is included. The overall ratings for the 10 ASEAN countries and the scores for each of the pillars are presented in the paper. The extent to which the RSM index is a valid indicator of road safety performance is also discussed.

Introduction

Transport plays a critical social and economic role, but failures of the system can have severe consequences for quality of life, including death and severe injuries (Ra'ed & Keating, 2014; Salmon, McClure, & Stanton, 2012). The social and economic losses associated with road trauma are enormous. According to the WHO Global Road Safety Report (2013) about 1.24 million people are fatally injured each year in road traffic related incidents. In addition, between 20 and 50 million non-fatal injuries are reported every year; with many people incurring disability as a result of their injury (Al Turki, 2014). It is clear that these numbers could be significantly higher if the effect of underreporting is taken into account, particularly in low- and middle-income countries.

One of the lessons of the recent literature in road safety is that road trauma is not equally distributed worldwide, with the incidence differing according to the level of economic development of the countries (Kopits & Cropper, 2005). To illustrate, it is estimated that 91% of road fatalities occur in low-income and middle-income countries (WHO, 2013). High-income countries have reported decreasing trends in deaths on their roads when compared with the increasing fatalities in low- and middle-income countries. Developed Regions such as Europe experience approximately 10.3 deaths per 100,000 inhabitants annually, whilst Africa and Asia have higher rates of 24.1 and 18.5 respectively (WHO, 2013).

The overall road fatality rate of the countries belonging to the Association of South-East Asian Nations (ASEAN) is 18.5 per 100,000 inhabitants; however the individual rates for countries differ substantially from 5.1 in Singapore to 38.1 in Thailand (WHO, 2013) with a median of 17.5. The variability in road trauma rates reflects underlying socioeconomic differences among the countries. Table 1 shows the distribution of ASEAN countries by socioeconomic level and fatalities per 100,000 population. It is apparent from this table that at the regional level, high income countries have lower rates of fatalities while middle and low income countries usually have higher fatality rates. This is consistent with similar studies that have found that in low income countries, the combination of poor road infrastructure, regulations, and emergency response expose drivers to more complex situations beyond their training and experience resulting in collisions while a slow emergency response potentially increases the severity of the original injury (Forjuoh, 2003; Huicho et al., 2012). It is hypothesised that economic differences among countries in the ASEAN region may lead to differences in road safety management and, therefore, in road safety outcomes.

Table 1. Socio-economic level and Fatalities per 100,000 population in the ASEAN region

Fatalities per 100,000 population	Socioeconomic Level			
	Low income	Lower middle income	Upper middle income	High income
Low (<10)		Philippines		Brunei Singapore
Medium (10-15)	Myanmar			
High (>15)	Cambodia Laos PDR	Indonesia Viet Nam	Malaysia Thailand	

*Adapted using data from the World Bank and World Health Organization

Road safety management includes the participation of governmental and organizational bodies in the provision of road safety strategies such as agreed targets and goals to be achieved, proposal of actions, regulation of vehicles safety standards, road design standards, and the organisation of a road crashes database (Bezerra, Kaiser, & Battistelle, 2015). At a regional level, evidence-based policy making requires data for monitoring the performance of the transport system segregated by country. However, qualitative and quantitative measures of the effectiveness of road safety management are difficult to integrate and the availability of these measurements varies across countries. So far, there has been little discussion about how to integrate the indicators established in five pillars outlined in the Global Plan for the Decade of Action for Road Safety 2011-2020. This integration is required to measure and compare road safety maturity and so identify opportunities for improvement.

Following the theoretical rationale of this paper, economic development is a major determinant of a region/country's maturity level and the outcomes of the road safety management systems. Worldwide the five-pillar model defined in Decade of Action for Road Safety 2011-2020 has been used as a surveillance tool for the independent outcomes but so far there is no global concept of road safety maturity. The aim of this paper is to commence the development of a new index for comparing road safety maturity integrating the five pillars model. This novel index has the potential to serve as a diagnosis tool of the road traffic system for detecting disparities and improvement opportunities. The index makes use of the WHO Global Road Safety Report (2013) as the most consistent and complete source of road safety indicators. The ASEAN region will be used as a case study in this paper due to different socio-economic and road safety patterns across its countries. This paper has been divided into four parts. The first part explains the Road Safety Maturity Index. This is followed by the case study of the ASEAN region. Finally, the discussion and conclusions of the case study and performance of the index are presented.

Road Safety Maturity Index

The Road Safety Maturity Index uses a content analysis approach and a binary methodology (report/no report) to integrate road safety outcomes. The main advantage of implementing this methodology is the flexibility for integrating qualitative and quantitative data, as is quite common in practice. This methodology has been widely used in other areas such as accounting/finance (Zorio, García-Benau, & Sierra, 2013), corporate social responsibility (Jain, Keneley, & Thomson, 2015), management (Eugene Fibuch & Arif Ahmed, 2013), among many others. It is important to note that this proposal is a preliminary test of a concept and how it is best operationalised, therefore further refinements of the model need to be explored.

The Index assigns numerical weighting to the indicators in the five pillars of the WHO Global Road Safety Report 2013 (WHO, 2013): road safety management, safer road and mobility, safer vehicles, safer road users and post-crash response. The value of the index per pillar ranges from 0 to 100%, and takes into account whether there is total, partial or non-implementation of certain actions. In addition, when possible, the rating of effectiveness of enforcement is included. Table 2 shows the final weightings and possible values for each of the indicators in the five pillars. In this preliminary version, the indicators of each pillar are equally weighted, in order to obtain a 100%, based on the total number of indicators. In the Pillar 1, for instance, each of the five indicators is assigned a 20%. Using the value criteria in Table 2, a value between 0 and 1 will be assigned based on the conditional rules developed with the binary methodology. If a country receives value 1 in each of the five indicators for Pillar 1, then these values will be multiplied by their respective weighting factor (20%), resulting in a perfect score of 100%. The possible overlap between indicators was avoided by including just a single indicator in the ranking. For instance, the uses of random breath testing and/or police checkpoints in the national drinking law were combined in the enforcement score. The overall level of maturity was obtained by averaging the score of each pillar by country. The levels of maturity by country or pillar are assigned using the scale described in the Figure 1. To the best of our knowledge, the proposed Road Safety maturity index is a novel approach to comparing commitment to improving road safety across all countries listed in the Global status report on road safety 2013.

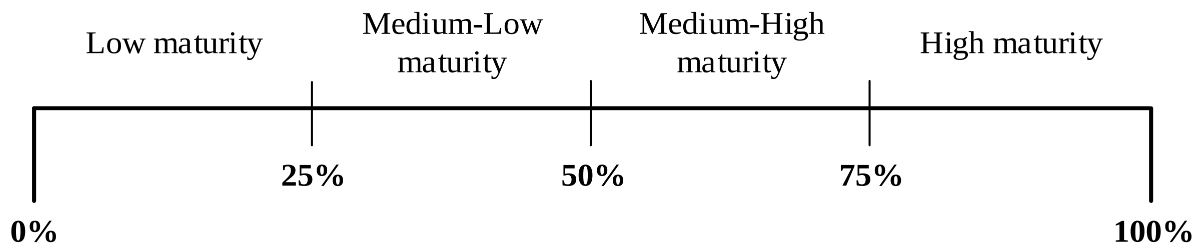


Figure 1. Scale for level of road safety maturity

Table 2. Road Safety Maturity Index indicators and weightings

Indicators	Weightings*	Value
Pillar 1. Road Safety Management	***100%***	
Lead Agency	20%	(1 if yes, 0 if no)
Funded in national Budget	20%	(1 if yes, 0 if no)
National road safety strategy	20%	(1 if yes, 0 if no)
Funding?	20%	(1 if fully 0.5 if partially, 0 if no)
Targets	20%	(1 if yes, 0 if no)
Pillar 2. Safer Road and Mobility	***100%***	
Formal audits required for new road construction	20%	(1 if yes, 0 if no)
Regular inspections of existing road infrastructure	20%	(1 if yes, 0.5 if partially, 0 if no)
Policies to promote walking or cycling	20%	(1 if yes, 0.5 if subnational, 0 if no)
Policies to encourage investment in public transport	20%	(1 if yes, 0.5 if subnational, 0 if no)
Policies to separate road users to protect VRUs	20%	(1 if yes, 0.5 if subnational, 0 if no)
Pillar 3. Safer Vehicles	***100%***	
Subscribes to UN World Forum on Harmonization of Vehicle Standards	25%	(1 if yes, 0 if no)
New car assessment programme	25%	(1 if yes, 0 if no)
Front and rear seat-belts required in all new cars	25%	(1 if yes, 0 if no)
Front and rear seat-belts required all imported cars	25%	(1 if yes, 0 if no)
Pillar 4. Safer Road Users	***100%***	
Penalty/demerit point system in place	14.3%	(1 if yes, 0 if no)
National speed limits	7.1%	(1 if yes, 0 if no)*(Enforcement/10)
Local authorities can set lower limits	7.1%	(1 if yes, 0 if no)*(Enforcement/10)
National drink driving–driving law	14.3%	(1 if yes, 0 if no)*(Enforcement/10)
National motorcycle helmet law	4.8%	(1 if yes, 0 if no)*(Enforcement/10)
Applies to drivers and passengers	4.8%	(1 if yes, 0 if no)*(Enforcement/10)
Helmet standard mandated	4.8%	(1 if yes, 0 if no)*(Enforcement/10)
National seat-belt law	7.1%	(1 if yes, 0 if no)*(Enforcement/10)
Applies to front and rear seat occupants	7.1%	(1 if yes, 0 if no)*(Enforcement/10)
National child restraint law	14.3%	(1 if yes, 0 if no)*(Enforcement/10)
National law on mobile phones while driving	-	-
Law prohibits hand-held mobile phone use	7.1%	(1 if yes, 0 if no)*(Enforcement/10)
Law also applies to hands-free mobile phones	7.1%	(1 if yes, 0 if no)*(Enforcement/10)
Pillar 5. Post-crash Response	***100%***	
Vital registration system	16.7 %	(1 if yes, 0 if no)
Emergency Room based injury surveillance system	16.7%	(1 if yes, 0 if no)
Emergency access telephone number(s)	16.7 %	(1 if yes, 0.5 if subnational/multiple, 0 if no)
Seriously injured transported by ambulance	16.7 %	% of Seriously injured transported by ambulance
Emergency medicine training for doctors	16.7 %	(1 if yes, 0 if no)
Emergency medicine training for nurses	16.7 %	(1 if yes, 0 if no)

** Values rounded to 0.1%*

Case Study of the ASEAN countries

The ten member countries of the Association of Southeast Asian Nations (ASEAN) are: Brunei, Indonesia, Malaysia, the Philippines, Singapore, Thailand, Viet Nam, Laos PDR, Myanmar, and Cambodia. In 2011, it was estimated that more than 75,000 people died in road crashes in ASEAN countries and many more sustained long term injuries (Turner, McIntosh, & Ogden, 2011). Figure 2 shows the distribution of fatalities across the ASEAN countries. Given that an estimated 630 million people live in this region (Clemente, 2015), improving road safety outcomes in ASEAN is not only important for the welfare and economic benefit of the populations of these countries, but also for the attainment of global goals for improved road safety.

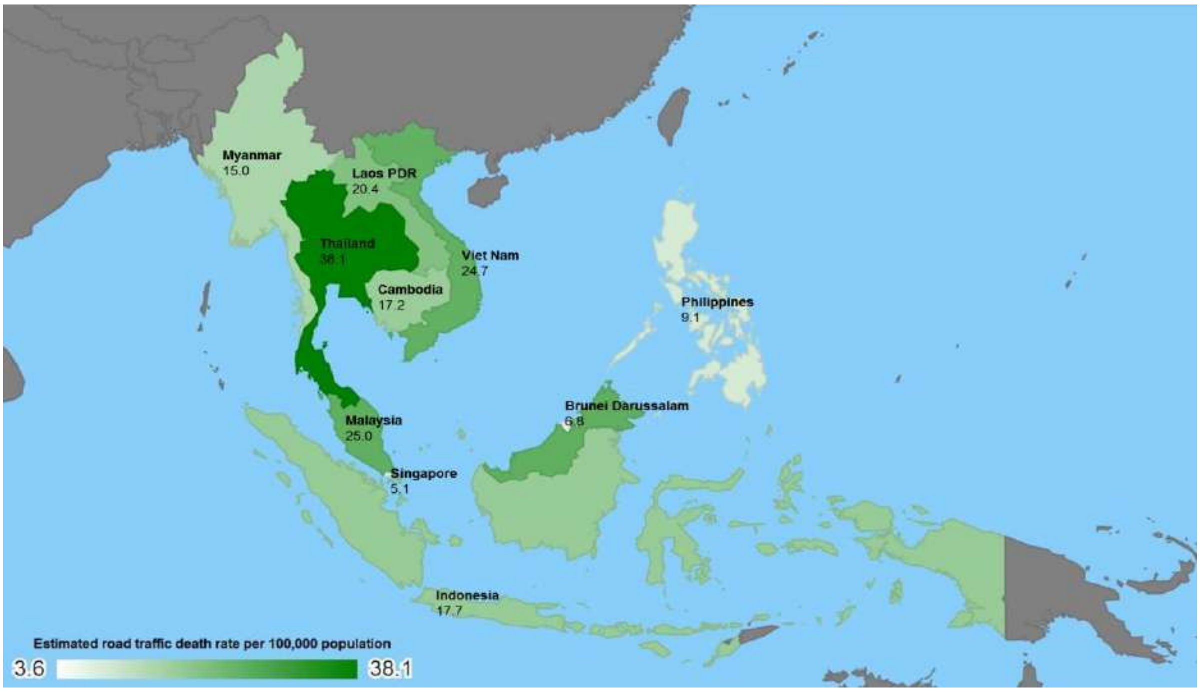


Figure 2. Road fatalities per 100,000 population in ASEAN.

Across ASEAN the motorization rates (including 2- and 3-wheelers) are high in Brunei and Malaysia (>700 per 1,000 population) but low in Myanmar and the Philippines (<100). Motorized 2- and 3-wheelers comprise the majority of vehicles in most ASEAN countries and this is unlikely to change because of their advantages in congested cities (See Figure 3). Yet reliance on these vehicles is associated with higher road fatality rates as shown in Figure 3. The pattern of use of these vehicles – often as family transport – makes it even more imperative that the road safety strategy should focus on addressing the vulnerability of users to road trauma (WHO, 2013). Figure 4 shows the strong relationship between fatalities and the prevalence of motorized 2-and 3-wheelers in the ASEAN region.

Methodology

The methodological approach for the development of this case study was a discussion of the five pillars proposed by The Decade of Action for Road Safety through a literature review. The road safety outcomes across the ASEAN countries were gathered directly from the WHO Global Road Safety Report (2013). The data by country were transformed using the proposed Road Safety Maturity Index. Independently, values for each pillar with an overall score by country were calculated and ranged from zero to approximately 100 percent.

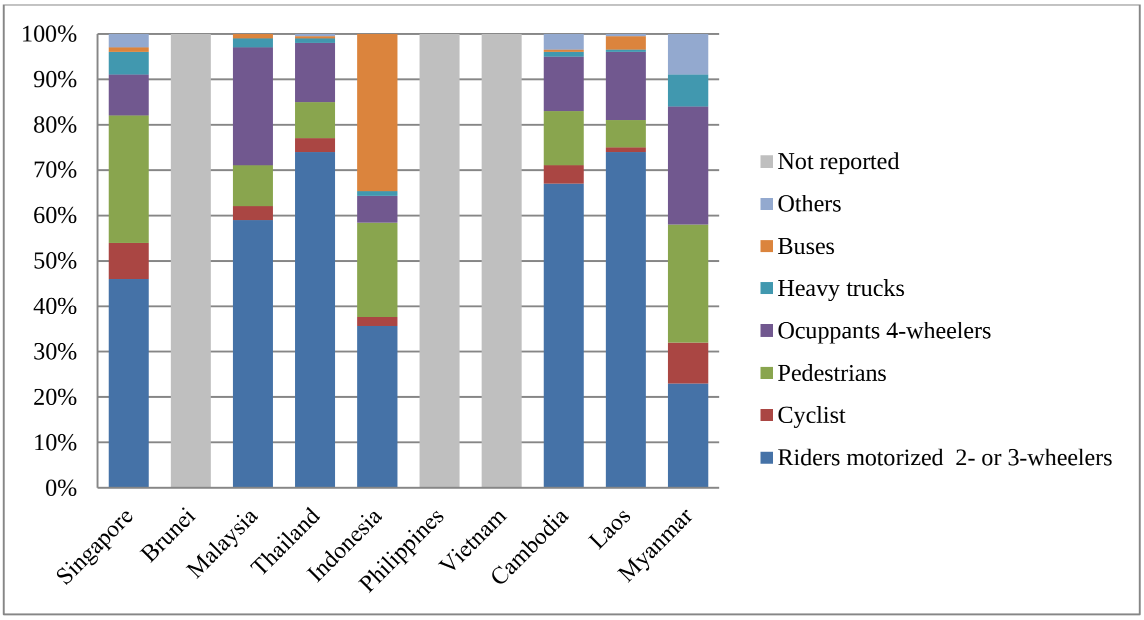
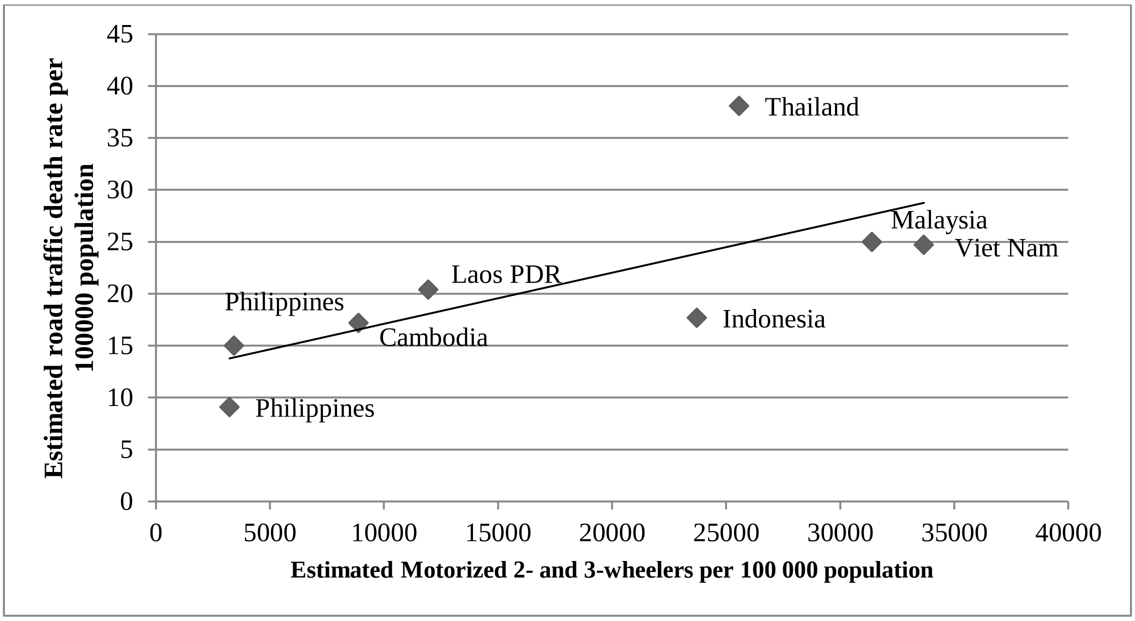


Figure 3. Vehicle composition in the ASEAN community



*Adapted from World Health Organization (No data available for Singapore and Brunei)

Figure 4. The number of road fatalities and the number of motorized two- and three-wheelers per 100,000 population

Results and Discussion

In Figure 5 the scores for each of the five pillars and the overall index by country are presented. The discussion of the main results related to each of the five pillars and its implications for the ASEAN countries are presented in the following sections.

Overall, the results showed that the ASEAN region has a medium-high road safety maturity level (62%). At a country-level, Malaysia ranks first (76%) owing to its consistent performance across the five pillars. Philippines (73%) and Viet Nam (72%) rank second and third respectively. The single most striking observation to emerge from the data comparison was that the overall score on the index did not seem to correlate well with the fatality rate. To illustrate, Singapore (71%) and Brunei (49%), both countries with the lowest road fatalities per 100,000 population, rank fourth and eight while Thailand, with the worst performance in fatalities, ranks sixth.

Looking more closely at individual pillars, it can be seen that the Pillar 4 “Safer Road Users” (39%) receives the lowest score among all of the pillars for the ASEAN region. This result was expected given that 80% of the countries are in the low to middle level of economic development. This is particularly true for Singapore; the country with the highest Per Capita Income (PCI) has the best performance in this pillar (74%). This finding is consistent with those of other studies that indicate the need to intensify the intervention on road users for countries in the early stages of economic development (Nantulya & Reich, 2003). However, these findings cannot be extrapolated to other high income countries like Brunei Darussalam; which has one of the lowest scores for enforcement (19%) but still a low level of fatalities per population. It should be noted that although the PCI values of Brunei Darussalam and Singapore were similar, the values of registered vehicles per 1,000 population and road density were very different. In estimates from the The World Bank (2014), Singapore has 230 vehicles per 1,000 population (2011 est.) while Brunei has only 46 vehicles per 1,000 population (2011 est.). Also, Singapore has 481 km. of road per 100 sq. km of land area (2011 est.) while Brunei has only 54 km. of road per 100 sq. km of land area (2011 est.). These differences are the most probable reasons for the low rate of road fatalities in Brunei Darussalam (Haque, 2011).

Pillar 1 “Road safety management” (81%) has the highest score among the pillars. The most common reason for losing points was because, generally, the national road safety strategy was only partially funded. Only Philippines (100%) has a perfect score in the Pillar 1, which may have influenced the low number of fatalities registered, by regional standards. This is supported by evidence showing that a road safety strategy for prevention will reduce road trauma (Bener, Abu-Zidan, Bensiali, Al-Mulla, & Jadaan, 2003). On the other hand, Indonesia (50%) has the worst score in the Pillar 1, because of the lack of a lead agency and only a partially funded road safety strategy. This situation has also been recently criticised by WHO (2015).

Pillar 2 “Safer road and Mobility” (65%), Pillar 3 “Safer Vehicles” (55%), and Pillar 5 “Post-crash response” (69%) show a medium-high maturity level. As shown in the Figure 4, Thailand scored poorly on Pillar 2 (20%), and this is a feature that has been reported by other researchers as one priority for the country (Islam & Kanitpong, 2008). Safe infrastructure, public transport promotion, and protection of vulnerable road user have been frequently linked with lower fatalities (Turner & Smith, 2013; Vesper et al., 2013), a challenge that is particularly urgent in Thailand at a regional and international level. The score on Pillar 3 was particularly low in Indonesia (0%) with no vehicle standards applied or vehicle regulations for seat-belts. However, with the recent creation of the ASEAN NCAP, some improvements have been achieved in this matter (Ward, 2014). Finally, performance on Pillar 5 “Post-crash response” was poor in low-income countries such as Laos PDR and Myanmar. This inequality in post-crash services due to economic development is frequently reported in the literature (Fleiter & Senserrick, 2015) and particularly in Myanmar (Thwe, Kanitpong, & Jiwattanakulpaisarn, 2013).

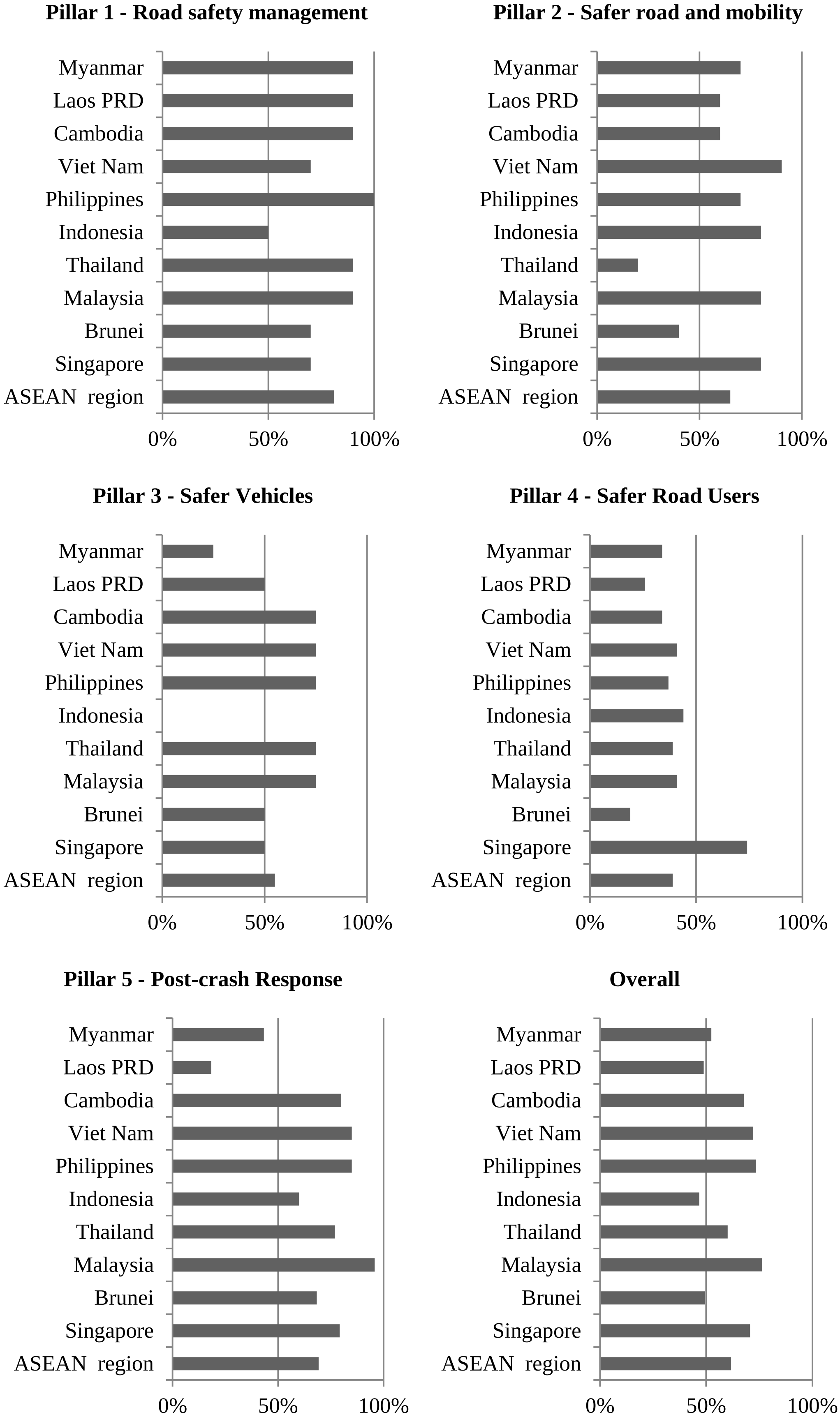


Figure 5. Road Safety Maturity Index values in ASEAN countries

Conclusions

A new index for comparing road safety maturity was developed and applied in a case study of the ASEAN countries. The Global status report on road safety 2013 provided the data for the index. This is the most consistent and complete source of road safety indicators world-wide. The results allowed differences to be identified, performance compared among countries, and improvement opportunities to be detected. Overall, the region has a medium-high maturity level; however, there are profound differences between countries. Some of these differences are explained by socio-economic factors that should be utilized in combination with the road safety outcomes (Klungboonkrong & Faiboun, 2014).

The results of the road safety maturity index were utilized for comparing the performance across countries and across pillars. Generally, the results were justified with the literature and no inexplicable findings were reported. However, the lack of consistency between the index and fatality rates needs to be considered in detail in future research. A possible explanation for this might be that the most of the pillars only include the existence of policies. This is insufficient since it ignores the two vital aspects of public policy, formulation and implementation (Egonmwan, 1984). A reasonable approach for tackling this issue is to start measuring degree of implementation and compliance with the policies and include this information in the later editions of the Global status report on road safety.

The benchmark results allow different jurisdictions to learn from others as a basis for developing measures and programmes which are aimed at increasing their own performance (Wegman & Oppe, 2010). The index could also be used to compare road safety developments over time between countries. Two main subjects for further research are identified throughout this paper. Firstly, it is necessary to examine the explanatory power of the index for fatalities, this could be achieved with a theory-base weighting for the variables inside and among pillars. Secondly, single measurements using binary methodology (report/no report) need an estimation of the degree of implementation.

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The incidence and characteristics of illicit drug related driver fatalities in Western Australia, 2000-2012

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Abstract

Background

Evidence continues to accumulate of the impairing nature of illicit drugs on driving and the prevalence of use among crash and non-crash involved drivers. The prevalence of illicit substances among drivers varies with the type of substance and whether the driver was involved in a crash. For example, illicit substances of all types have been detected in up to 33% of fatally injured drivers with cannabis being the most frequently detected substance (Beasely, Beirness & Porath-Waller, 2011). Among non-crash involved drivers, between 4%-18% self-report having driven after using illicit drugs (AIHW, 2011), while up to 3.5% of drivers subject to a roadside oral fluids test in one Australian state have tested positive (Davey, Davies, French, Williams & Lang, 2005). Research has also identified that certain drivers have a higher risk of illicit drug-driving, including males (e.g., Blencowe, Pehrsson, Mykkanen, Gunar & Lillsunde, 2012), younger age persons (e.g., Clarke, Ward, Bartle & Truman, 2010) and those that engage in other on-road risk behaviours such as failing to wear a seat-belt (e.g., Beasley et al., 2011), drink-driving (Ashbridge, Poulin & Donato, 2005), and unlicensed driving (e.g., Boorman & Owens, 2009). Annual reporting of illicit drug driving in Western Australia (which commenced in 2008) is limited to fatally injured drivers and general descriptors such as the type of substance, age and gender of driver, road user status, and day of week. Unfortunately the reports fail to provide a detailed understanding of the trend and pattern of illicit drug involvement over time and associated driver and crash risk factors. This paper reports on the selected findings of a recent in-depth investigation of illicit drug-driving in Western Australia during the period 2000-2012. The findings of two of the study's objectives to be considered in this presentation are:

- To document the incidence, trend and characteristics of illicit drug related motor vehicle driver and motorcycle rider fatalities, and,
- The multivariate modelling of driver/rider and crash risk factors for an illicit drug driver/rider fatality.

Method

WA Police crash records of drivers and motorcycle riders fatally injured on Western Australia roads 2000-2012 were linked with WA ChemCentre toxicology records to identify the presence and nature of illicit drugs, alcohol and other drugs among drivers/riders. A total of n=1,375 linked records were extracted for analysis, representing approximately 90% of the n=1,523 motor vehicle drivers and motor cycle riders reportedly killed during the period on Western Australian roads. Univariate analyses were undertaken of all crash, driver, and drug variables. The main outcome variables were the binary classification of the fatality as illicit drug related and the annual rate (per 100,000 motor vehicle driver licences issued) of illicit drug related fatalities. An illicit drug-related fatality was defined as one where toxicology records for the fatally injured driver/rider confirmed the presence of one of the three illicit drugs prescribed in Section 64AC of the WA Road Traffic Act 2000 - Cannabis (showing as THC), methylamphetamine, MDMA (ecstasy) - or any other substance the ChemCentre subsequently advised to be 'illegal' or prohibited. Multivariate binary

logistic regression was also undertaken to model the risk factors for fatally injured drivers who tested positive for an illicit drug.

Results

Approximately 23% (n=312) of fatally injured drivers/riders tested positive for one or more illicit drugs during the period 2000-2012 at a rate of 22.46 per 100,000 licensed motorcar drivers/riders. The annual illicit drug related fatality rate per 100,000 licensed drivers (Figure 1) did not significantly vary over the period 2000-2012 ($F (1,11)=0.54$, $p=.477$; unstandardized slope -0.025; $t= -.736$, $p=0.477$) though there is some evidence of a general decline in the rate post 2007.

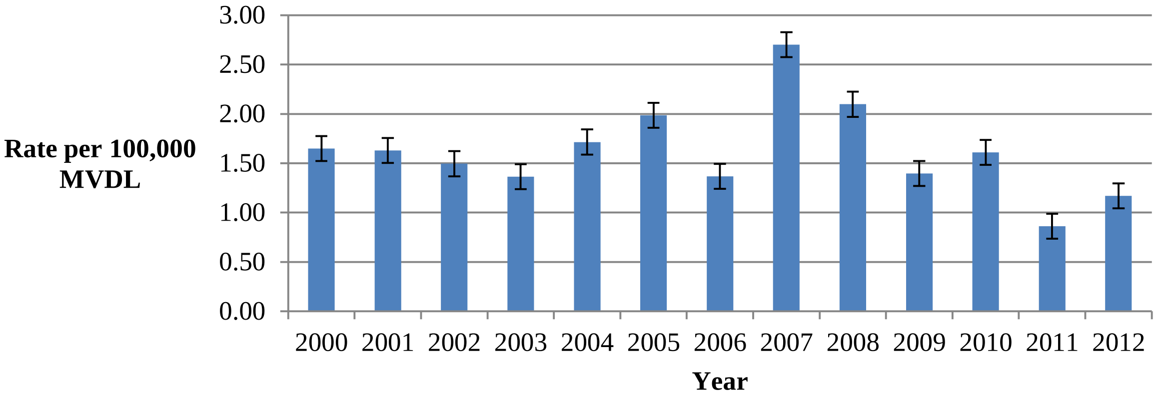

Figure 1. Annual rate of detection of an illicit drug among fatally injured drivers/riders per 100,000 Motor Vehicle Driver Licences issued; Western Australia 2000-2012

A total of n=383 positive tests for illicit substances were recorded for the n=312 illicit drug related driver/rider fatalities. Approximately 62% of driver/riders who tested positive did so for THC (cannabis) alone. The next most common detections were methylamphetamine alone (14.7%), and THC and methylamphetamine in combination (13.6%). Approximately 6% of drivers/riders who tested positive did so for MDMA.

Univariate analyses revealed statistically significant variation in the proportion of fatality injured drivers/riders testing position for illicit drugs for driver gender and age; driver licence status, Blood Alcohol Concentration level and the presence of selected pharmaceuticals; region and police district of crash, and type and time of day of crash. Multiple logistic regression using the preceding variables returned significantly greater adjusted odds of testing positive for an illicit drug when the fatally injured driver/rider was male (OR=1.56), under 40 years of age (OR=4.13), had no authority to drive (OR=2.80), returned a BAC level between 0.050-0.079gm% (OR=2.10) and 0.080-0.140gm% (OR=2.01), and tested positive for benzodiazepine use alone (OR=2.71) and in combination with opioids (OR=3.45).

Discussion

This study has highlighted the potential contribution of illicit drugs, alone and in conjunction with alcohol and other drugs, in the fatal injury of Western Australian drivers/riders. Cannabis was confirmed as the most frequently detected illicit substance among crash involved drivers, with males, younger age persons, and those who are unlicensed and driving under the influence of alcohol as persons most at risk of illicit drug driving resulting in a fatality. There was some evidence to suggest, subject to further in-depth analysis, that the annual rate of illicit drug driving fatalities was trending downward post 2007 in association with the introduction of the roadside oral fluid testing program. These findings and those of the larger study (Palamara, Broughton &

Chambers, 2014) resulted in a number of recommendations being proposed, including an increase in the annual number of roadside oral fluid tests conducted - particularly in the non-metropolitan area of Western Australia – and a change in policing to follow up a selection of drivers who initially test positive for alcohol with an oral fluid test for illicit drugs as per the program that was recently introduced in Victoria.

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Drink Driver Rehabilitation and New Developments

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Abstract

Drink driving continues to be a major public health concern. Significant reductions in road fatalities have been achieved due largely to the Safe Systems Approach to road safety. However, serious injury due to road trauma has increased in most Australian jurisdictions. Some subgroups of drink drivers such as young drivers and Indigenous drink drivers are vulnerable to road trauma and have been less responsive to countermeasures based on the deterrence philosophy. Drink driving rehabilitation programs that use a combination of deterrence, education and social control models have been moderately successful in reducing recidivism. However, most of these programs do not adequately address alcohol related health concerns or the needs of drink drivers in remote and rural areas. Scant attention has also been given to the use of brief online drink driving interventions. The 'Under the Limit' (UTL) drink driving rehabilitation program has recently been revised to ensure that its content is contemporary, relevant and evidenced based. CARRS-Q has also developed a brief online program that targets first time convicted drink drivers who have a BAC under 0.15g/100mL and a culturally sensitive program that targets Aboriginals and Torres Strait Islanders living in rural and remote areas. These new developments will be discussed in the context of the most effective road safety educational policy and practice.

Overview

During the last decade (2003-2013) traffic fatalities have decreased by 23% (BITRE, 2014) in Australia. The reduction in road fatalities has been broadly accredited to a national road safety strategy (NRSS) that encourages State jurisdictions to adopt a Safe System Approach in plans that reflect a vision that no person should be killed or injured on Australian roads. This approach is one that aims to develop a safe road transport system that accounts for road user behaviour by improving road conditions, vehicular technology and enforcement of traffic laws (ATC, 2011).

Targeting seat belt usage, reducing speed through camera programs and drink driving through random breath testing (RBT) has significantly contributed to the reduction of road fatalities (BITRE, 2010). However, based on the BITRE (2014) road toll figures over a decade, approximately 14,000 people have died due to a road related trauma. Approximately 32,000 people suffer a road related serious injury requiring hospitalisation (ATC, 2011) annually and in most jurisdictions serious injures due to traffic crashes increased between 2000 and 2009 (AIHW, 2012). Subgroups including: young drivers aged 17-25 years; older drivers in the 65+ age group; and drivers who identify as an Aboriginal or Torres Strait Island (ATSI) person are more vulnerable to serious injury or death on the roads (ATC, 2011, AIHW, 2007) through road trauma. Young Australians comprise 25% of the victims (ATC, 2011) and Indigenous Australians are 3 times and 1.4 times more likely to suffer a serious injury or death, respectively on the roads compared to their non-Indigenous peers (Harrison & Berry, 2008; Moller, Thomson & Brooks, 2003).

The health, social and economic costs of road trauma is about $18 billion annually (ATC, 2008) and has motivated researchers to identify the risk factors associated with drink driving anticipating this will enable the development of effective countermeasures. Drink drivers tend to be aged less than 35 years and drivers with a high BAC range (≥ 0.15g/100ml) are slightly older with a history of alcohol problems and other driving and non-driving offences (Leal, King & Lewis, 2008). Approximately 15% - 30% of drivers continue to drink and drive in spite of road safety measures (Leal et al., 2008; Owens & Boorman, 2011).

Repeat drink drivers appear to be less responsive to drink driving countermeasures (Freeman & Liossis, 2002; Harrison, Newman, Baldcock & Mclean, 2003) underpinned by the theory of specific and general deterrence (Homel, 1988; Homel, 1993). Specific deterrence measures, in particular which include such sanctions as fines, license disqualification and, in some cases incarceration have failed to impact significantly in reducing the extent of drink driving among Indigenous peoples (RTA, 2008).

A study by Freeman and Watson (2009) revealed that punitive sanctions only account for a portion of the deterrent effect and therefore other factors may play a role in motivating drink drivers to separate drinking and driving. Intervention programs have attempted to address some of the psychological and situational factors that contribute to drink driving. These legally coerced interventions combine punishment, education, rehabilitation and probation supervision and seem to be most efficacious in reducing recidivism among drink drivers (DeYoung, 1997; Wells-Parker, Bangert-Downs, McMillen, & McWilliams, 1995). Although there is debate about the effectiveness of coercing people with general substance dependence into treatment some clinical experience and outcome studies suggest coercion is fundamental to positive treatment outcomes (Klag, O'Callaghan, & Creed, 2005; Miller & Flaherty, 2000). In light of this research a variety of drink driving education and/or rehabilitation programs have been implemented in Australia based on a multi component approach combining both educational and punitive measures. Table 1 depicts an overview of the nature, focus and effectiveness of these programs.

Table 1: Australian Drink Driving Rehabilitation Programs

	Queensland	**New South Wales & ACT**	**Northern Territory**	**Victoria**
Name	Under the Limit Drink Driving Rehabilitation Program (UTL)	Traffic Offender Program (TOP) - Sober Driver Program (SDP)	Drink Driver Education Program	Drink Driver Education Program
Focus and Length	Education, Rehabilitation & Assessment, based on CBT principles Fees apply Weekly sessions (1.5hr) over 11 weeks Aimed at repeat offenders	TOP - Education - Weekly sessions (2hr) over 8 weeks Fees apply SDP - either 9 weekly 2 hour or 6 weekly 3 hour sessions	Education - 1st session (10hours); 2nd session (4 hours) for repeat/ high range BAC Fees apply	Assessment & Education - 8 hours alcohol problems – not all components Are compulsory Fees apply
Legislation and Support after program	Part of sentencing system – part of an optional Court ordered Probation Order	TOP – pre-sentence diversionary – Optional SDP – part of sentencing system completed as part of an optional Court ordered Probation Order	part of sentence system - requirement prior to re-licensing for drink drivers disqualified from driving	Independent of the sentencing system but a an administrative requirement prior to re-licensing for some offenders
Target	Urban; Regional	Urban; Regional	Regional	Urban, Regional

Audience				
Evaluation	Outcome: Siskind, et al. (2001) – reduced recidivism of 55% for high risk, serious repeat drink drivers	Outcome: TOP –RTA (1999) – reduced recidivism of 25% SDP - Mazurski et al. (2011) – recidivism reduced by 44%	Outcome: Dwyer & Bolton (1998) – re-offending rate of 12.85% within 2 years following re-licensing	Process: Hennessy (1998) – good to very good; Sheehan et al. (2005) – 23 recommendations made to improve the program

Australian Drink Driving Rehabilitation Programs

The majority of these interventions have been informed by theoretical frameworks such as the theory of planned behaviour (Ajzen, 1991; Ajzen & Fishbein, 2005), trans-theoretical stages of change (Prochaska, DiClemente, & Norcross, 1992), elements of deterrence theory (Homel, 1993; Homel, 1988) and social control models (Sheehan, 1994). The deterrence aspect of the interventions includes the loss of licence, fines and coerced participation in drink driving education programs. Drink drivers are co-opted into participating to avoid a more serious consequence.

The educational and rehabilitation component of the interventions are generally informed by the theory of planned behaviour and stages of change theory. For instance, in regards to the theory of planned behaviour the content is delivered in a manner to facilitate a change in attitude toward drink driving behaviour. Additionally, it is expected that participants increased knowledge and social skills will change their subjective evaluation of the risks and benefits and so result in a behavioural intention to self-control, resist social pressures and rationally act to avoid the repetition of drink driving.

A key aim is to motivate drink drivers toward an action based stage of change based on Prochaska's (1994) stages of change model that involves five discrete stages: pre-contemplation; contemplation; preparation; action; and maintenance. The model encompasses the idea that individuals can relapse and move between the five stages, allowing individuals to recycle through the stages between pre-action to action. Drink driving programs facilitated in Queensland and Northern Territory utilise components of the stage of change model to effect change amongst offenders.

Some Australian drink driving educational interventions have been available since the early 1990s though they vary in length, content, delivery style and costs across jurisdictions. New South Wales (NSW) for example, offers the Traffic Offender Program (TOP) for all traffic offenders and the Sober Driver Program (SDP) for repeat drink drivers. The TOP is available on a voluntary basis to persons who plead guilty to any traffic offence and traffic offenders are referred to the program as part of a diversionary pre-sentence process. General road safety information is provided by a variety of accredited providers or government agencies on a fee basis over 8 sessions of 2 hours duration each. An evaluation of the Mt Penang TOP indicated recidivism could be reduced by 25% (RTA, 1999).

The Sober Driver program (SDP) targeted more serious repeat drink drivers. This program aimed to reduce recidivism through educational and cognitive behavioural therapy offered in groups. The SDP is made available to repeat drink drivers post sentencing as part of a good behaviour bond and delivered by probation officers. The program can be undertaken by attending either a nine weekly sessions of 2 hours duration or three weekly sessions of 6 hours duration. An evaluation of the SDP involving a comparison group and recidivism rates over 2 years indicated that individuals who completed the program were 43% less likely to re-offend (Mills, Hodge, Johansson, & Conigrave, 2008).

In Victoria persons convicted of a drink driving offence are required to undertake an 8 hour driver education program and possibly an assessment before they can be re-licensed. The driver education programs are provided by private or non-profit agencies and the content provides information to encourage a change in the drink driver's drinking behaviour and patterns of individual and community drinking. A process and formative evaluation was undertaken by Hennessy (1999) and participants generally rated the programs as good to very good. However, Hennessy (1999) noted there were inconsistent standards of teaching across programs and some facilitators lacked specialised knowledge. Additionally, there was a need to audit the quality of the programs. A review by Sheehan, Watson, Schonfeld, Wallace and Partridge (2005) suggested making relicensing a condition of education and assessment was not the most effective approach. The review additionally noted there was a need to ensure the program meets best practice and addresses issues for high risk drink drivers.

A Drink Driver Education Course has also been conducted in Northern Territory since 1995 and uses a systems approach, including punitive measures, social learning principles, harm minimisation, motivational interviewing and the stages of change model (Dwyer & Bolton, 1998). A systems approach encourages drink driving to viewed and addressed having regard to the contextual factors that may facilitate or impede drink driving such as the liquor industry, police, health authorities, educational bodies, politicians, insurance companies, clubs and community agencies. This approach will encourage the development of more realistic protective factors to reduce drink driving and how to avoid risk factors associated with drink driving.

There are two modules to the Northern Territory drink driver education program. Offenders with high BACs or repeat offences have to complete both modules. The program has also being tailored to meet the needs of the general population and customised for Indigenous people. The course content is research-based but is delivered in a manner to utilise participants' life experiences. The course provides participants with knowledge about drinking, plans to avoid drink driving and controlled drinking strategies. An evaluation of 321 participants indicated that 41(12.8%) had committed a further drink driving offence and offenders who were required to complete the two modules recorded a higher re-offence rate (Dwyer & Bolton, 1998). The authors suggested that the higher re-offence rates for those who completed the two modules may reflect a lifestyle that maintains or encourage alcohol consumption. The authors also acknowledged the evaluation was limited due to lack of pre-course reoffending rates, law enforcement variations, bias that may have occurred in selecting participants for the intervention modules as well variations in data entry.

Under The Limit Drink Driving Rehabilitation

The Queensland 'Under the Limit drink driving rehabilitation program' (UTL) was initially trialled in the early 1990s and has been operating in excess of 20 years. Over 12,000 drink drivers have completed the UTL. The program has been reviewed and modified throughout this time to reflect contemporary evidence and relevance. While the UTL is available State wide to people with or without a drink driving record and prior to sentencing, the program is largely used as a post-sentencing option for high range (BAC ≥ 0.15g/mL) first offenders and repeat drink drivers. Drink drivers must voluntarily agree to be admitted to a probation order and attend the UTL for a fee. If the drink driver agrees to participate in the UTL Magistrates have the discretion to reduce or waive the fine.

The original UTL program comprised eleven sessions of 1½ hours duration conducted in groups of 8 to10. The aim of the UTL is to provide education about the impact of drink driving, address drinking problems and situational factors that lead to driving after drinking and change attitudes towards drink driving. During the program sessions participants learn to track their level of drinking, develop a plan to manage their drinking and learn assertion skills and strategies to assist them to avoid future drink driving. Attendance at UTL sessions is monitored and enforced by a probation officer. Probation supervision also offers the opportunity for the drink driver to address serious alcohol concerns through other agencies such as the Department of Health.

For a number of years the UTL was offered in a distance education mode so that individuals living in rural or remote areas could participate. However, there were a limited number of individuals who opted to partake in the UTL distance program and it was too cost prohibitive to continue. The program has also been offered to Indigenous persons convicted of drink driving but the UTL was found to lack cultural sensitivity and has not been particularly successful for indigenous drink drivers. The use of alcohol ignition interlocks was also trialled in conjunction with the UTL and legislation provides that some drink drivers may be subject to an ignition alcohol interlock program.

An evaluation of the UTL completed by Ferguson, Schonfeld, Sheehan and Siskind (2001) suggested that over time, the program did appear to impact on offenders' intentions to change their driving behaviours to avoid a future drink driving offence, with a subsequent decrease in self-reported drink driving being seen among the UTL group relative to the control group. The UTL did not impact on other lifestyle areas such as mental health, social support, knowledge, attitudes and alcohol consumption profiles. Successful completers had an overall reduced recidivism of 15% compared to controls but there was no difference in recidivism rates been the UTL and control groups for the first offender's group with a BAC lower than 0.15g/100mL (Siskind, Sheehan, Schonfield, & Ferguson (2000). When the impact of the UTL was examined more closely, offenders with a high BAC (≥ 0.15g/100mL) and prior drink driving offence achieved a reduced recidivism rate of 55% compared to controls.

New Developments in Queensland

Despite the moderate success of the UTL and some similar programs in other jurisdictions there are a number of concerns that could be addressed to ensure adherence to best practice. These include catering for the needs of different offender groups such as younger and older offenders, less serious versus more serious drink drivers as well as Indigenous offenders. While some of the existing programs attempt to assess for serious alcohol problems and recommend referral for more in-depth treatment none of them really consider wider alcohol-related health issues. Most programs except perhaps for the Northern Territory program do not consider the cultural context of drivers and have been essentially designed to meet the needs of an urban non-Indigenous population. The value of brief online interventions for first time drink drivers with low BACs appears to have also been overlooked in most Australian jurisdiction. The reason for this is not clear and the efficacy of a brief online drink driving intervention for first time offenders needs to be established in the Australian context. Drink driver education/rehabilitation programs also need to be informed by a sound theoretical framework and be delivered in a high quality and consistent manner. The lack of this approach in some jurisdictions creates difficulties for outcome evaluation studies.

Over the last 12 months the Centre for Accident and Road Safety Research -Queensland (CARRS-Q) has been revising UTL and designing and trialling other drink driving educational programs that target specific groups such as first time drink drivers and Aboriginal and Torres Strait Islander people living in rural and remote areas. The revision seeks to ensure that its content is contemporary and aligns with current evidence based practice. CARRS-Q staff has considered concerns raised by some Magistrates and Probation Officers regarding the program's length and cost and its suitability for rural and remote parts of Queensland. The revised program is designed for delivery across 6 by 2 hour sessions and the fee has been reduced. The program remains informed by aspects of the theory of planned behaviour, stages of change model, deterrence theory and social control models. In addition, it has incorporated some components of the Health Action Process Approach (HAPA) and addresses motivational, planning and maintenance issues.

The HAPA model connects the motivational, behavioural enactment models and multi-stage models, including stages of change model, social cognitive theory and theory of behavioural change (Armitage & Connor, 2000; Schwarzer, 1992). It also expands on planned behaviour theory and social cognitive theory that are not developed to explain and predict health behaviour. The basic assumption of the HAPA model is that the initiation and maintenance of health behaviour must be considered as a process consisting of at least two stages: a motivational phase and a volition phase. The latter is further subdivided into a planning phase and a maintenance phase.

The revised UTL includes most of the previous content, though updated and additional material that addresses motivational issues and self-efficacy to encourage maintenance of positive changes. Material has been incorporated which reflect current learning, technology and relevance. The key content of the revised UTL includes providing participants with information about standard drinks, how to monitor alcohol consumption through a drink tracker diary, assertion skills, the dangers of drink and drug driving, options to stop drink driving and the impact of alcohol on health. Importantly, participants learn how to self-assess the risk level of their drinking and/or problem and develop a plan and strategies to reduce drinking and avoid drink driving. Participants engage in group activities that assist them to build self-efficacy and confidence to maintain a low risk drinking lifestyle thereby avoiding drink driving. The revised UTL is currently being trialled through a number of Magistrates courts and will be available as both a pre-sentencing and post-sentencing option.

CARRS-Q is also trialling a brief online intervention, The “Steering Clear First Offender Drink Driving program” (SCP) for first time drink driver offenders. This intervention responds to findings that most convicted drink drivers do not re-offend though about 30 to 40% self-report drink driving following the first offence (Leal et al., 2008; Owens & Boorman, 2011; Wilson & Sheehan, 2013). A brief intervention provides the opportunity for first time drink drivers to become more aware of the impact of drink driving and the factors associated with their drink driving episode. This knowledge may assist them to strengthen their resolve not to become a repeat drink driver. The effectiveness of brief interventions conducted largely in hospital accident and emergency rooms for patients presenting with alcohol related problems has been established through meta-analytic studies which demonstrate a reduction of hazardous alcohol consumption (Bertholet, Daeppen, Wietlisbach, Fleming, & Burnand, 2005).

The SCP developed by Hollie Wilson and a CARRS-Q research team is a new brief, step by step 2 hour program which is undertaken using the internet at home, mobile phone or tablet. It is designed for first time drink driving offenders who have a BAC under 0.15g/100mL and to educate drink drivers about the impact of alcohol on driving and to get them to think about strategies to avoid future drink driving. Participants also have ongoing access to a mobile friendly app that they can be used to monitor alcohol use and make plans to avoid drink driving. A certificate of completion can be tendered to the Magistrate. The program is currently being trialled in a number of Magistrates Courts in Queensland.

A culturally sensitive Indigenous drink driving rehabilitation program, ‘Hero to Healing’ (HTH) has recently been developed by Michelle Fitts with the support of Indigenous Community Elders and leaders as well as professionals who provide alcohol programs in remote Indigenous communities (Fitts & Palk, 2015ab). It has been trialled in two Far North Queensland communities and a Northern New South Wales community. The HTH program is based on components of the community reinforcement approach (CRA) and the findings from research conducted with regional and remote communities in Far North Queensland and regional New South Wales (Fitts & Palk, 2015ab). The CRA is based on the belief that the environment can positively reinforce substance abuse behaviour and treatment includes eliminating the factors that encourage substance abuse as well as learning new coping behaviours with the support of significant others (Miller, Meyers, & Hiller-Sturmhofel, 1999).

The HTH program is conducted across 4 sessions of 2 hours duration each and participants discuss the social and psychological impacts of drink driving in the context of kinship pressure, risk taking, pre-colonial Indigenous values, general alcohol problems and alcohol and cannabis education. Significant others particularly community Elders participate in the program and issues are discussed in the light of story-telling, yarning, visual media and cultural activities. Upon completion of the program it is envisioned that drink driving will be discouraged by the wider community through local meetings. Funding is currently being sought to implement the HTH in a number of remote Indigenous communities and to evaluate its effectiveness. The evaluation will include a process and outcome evaluation that will examine the perception of program facilitators and participants, impact on participants' lifestyle, driving and drink driving recidivism.

Conclusions

Drink driving education/rehabilitation programs that involve a multicomponent approach through coercive techniques, punitive measures, probation supervision and education/rehabilitation appear to be effective in reducing recidivism. However, there are concerns about the ability to evaluate these programs due to the difficulties of controlling for factors such as delivery style, diversity of content, inconsistent policing and lifestyle factors that may influence outcomes. Programs need to be monitored closely to ensure content remains contemporary and based on best practice evidence and delivered in a high quality and consistent manner. Most current programs fail to cater for various subgroups of drink drivers, particularly Indigenous drivers. Scant attention has also been given to the value of brief online interventions that may be suitable for first time convicted drink drivers, most of whom are unlikely to re-offend.

Although there is debate about the effectiveness of coercive treatment some research seems to indicate that coercion is fundamental to the treatment of resistant substance users. Coercion also may be a key to providing an opportunity for repeat drink drivers to be exposed to education about their alcohol patterns to address lifestyle factors that encourage a reduction in drinking and skills to avoid drink driving. While education and assessment of risk levels of alcohol consumption are important components of a drink driving program, lifestyle and alcohol-related health concerns also need to be addressed. Repeat drink drivers in particular need to gain the confidence and motivation to maintain a plan that includes reducing alcohol consumption and strategies to avoid future episodes of drink driving.

The Queensland HTH program attempts to address drink driving concerns in a culturally meaningful way for Indigenous people living in remote and rural areas. The content and delivery style of the program was developed after extensive consultation with Elders and community members in Indigenous communities. Feedback from participating trial communities about the content and delivery style has been positive and effectiveness will be explored in the program's next planned phase. The online SCP was developed following consultations with drink drivers and professionals involved with delivering rehabilitation services to offenders. This program is currently being trialled and its efficacy is not known at this stage. The revised UTL program has been implemented and an evaluation framework for this program is being developed.

It is also important that best practice evaluation frameworks be established to examine the effectiveness of the various types of drink driving education and rehabilitation interventions. Previous evaluations of these types of programs have often lacked an adequate comparison group and have been marred by inaccurate data, variations in law enforcement and a failure to control for the influence of extraneous variables (e.g., road safety campaigns and other road safety strategies being implemented simultaneously). It is acknowledged that it is difficult to isolate drink driving rehabilitation interventions from other road safety strategies but evaluation frameworks must strive to limit the impact or account for the influence of extraneous variables. Ideally, an adequate evaluation framework should include a random sample of drink drivers subjected to a rehabilitation intervention compared with a control group that has been randomly selected after matching of driver characteristics and offence history. It would also be very valuable to obtain the prior drink driving history and other criminal events for the intervention and control group. The evaluation should not only consider recidivism rates but the impact of the program on other life style factors such alcohol consumption, safer driving and prosocial attitudes.

To some extent the new developments in Queensland drink driving rehabilitation programs address the needs of drink drivers in a targeted manner. Future drink driving rehabilitation programs need to be designed to meet the specific needs of subgroups of drink drivers that may be more vulnerable to road related trauma taking into account age, gender alcohol-related health concerns and culture. Serious consideration by all jurisdictions needs to be given to legislating for drink driving/rehabilitation programs to become mandatory as a pre-sentencing bail condition and/or as part of a post-sentencing Court ordered bond or probation condition.

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Exploring the role of healthy distraction on driver performance

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Abstract

Looked-but-failed-to-see crashes describe car crashes in which drivers are apparently looking directly at an unexpected object on the road yet report failing to see it, resulting in a collision. A cognitive mechanism that explains these crashes is inattentional blindness (IB); a phenomenon that occurs when observers fail to notice an unexpected, though clearly visible object in their visual field when their attention is engaged elsewhere. We have been conducting a series of experiments in which we use a static, driving-related, IB task. The primary task involves making safety decisions about briefly-presented driving scenarios. After a given number of trials, an unexpected stimulus, e.g., a person, animal or object, is placed on the side of the road. We have demonstrated differential processing of unexpected stimuli, suggesting that drivers make broad attentional sweeps of all objects when driving. In a separate stream of research, we have also demonstrated that attention can increase for an unexpected stimulus in IB in the presence of distraction. Distraction refers to an additional stimulus that draws attention away from a primary task, however these results suggest that task-irrelevant distractions have the potential to facilitate conscious processing of unexpected stimuli such as hazards in driving. Combining the two streams of research, it is possible that transient distraction when driving might facilitate attention, suggesting that some distraction may be a good thing. These results have important implications for understanding driver distraction, as well as models of attention where the effect of distraction on attention may reflect a U-shaped function

Introduction

The primary focus of the attention literature in driving is about maintaining attention and exploring which factors might distract attention away from this goal. With the development of more sophisticated in-car technology, and the increasing visual complexity of the driving environment, there is substantial research investigating the impact of increasing distractions on driving performance. A current search of the scientific literature for "driver distraction" reveals almost 500 scientific articles in the last 10 years (Web of Scienceapps.webofknowledge.com/). However, the reality is that attention must be distractible. Behaviourally relevant stimuli such as a pedestrian, dog, runaway ball, or cyclist, must capture the attention of the driver, and failure to do so will have disastrous consequences. Research in our lab and others has been motivated by understanding the factors involved in attentional capture; what the circumstances are in which attention is captured, and more importantly, under what circumstances does an unexpected object fail to capture attention? Specifically, recent research has pointed to the intriguing possibility that a certain level of distraction is in fact necessary for optimal performance in detecting unexpected objects – a phenomenon that may be referred to as 'healthy distraction'. Thus, the current paper is a brief review of the relevant literature with a segue into some of the research that has been conducted in the Applied Cognition and Transport Safety (ACTS) Laboratory at the Australian National University. This research has been conducted over the last 5 years by the author, colleagues and various students, who have been acknowledged in the appropriate section. This review concludes with the suggestion that *some distraction when driving may be a good thing by increasing driver awareness.*

Attentional load and under-load in driving

Psychological theories of attention are united in the evidence that as cognitive load increases, attention decreases. (e.g., Cartwright-Finch & Lavie, 2007; Lavie, 1995). There are good cognitive models to explain why this occurs. The basic premise is that there is limited attentional capacity to devote to the world around us at any time, and as the requirements for attention increase, the cognitive resources that can be devoted to specific tasks decreases. This is referred to as Cognitive Load Theory (Lavie 1995). Thus, driving consumes a certain amount of attention, if distracting events are added to the driving situation, such as rain, heavy traffic and the driver talking on a mobile phone. Each of these events divert some of the limited cognitive capacity, away from the primary task of driving the car, the likely consequence of which is that the driver becomes increasingly less likely to detect hazards and unexpected events. However, both anecdotally and empirically, there may be utility in also looking at the other end of the attention spectrum; when driving has become so automatic that we fail to engage our attentional system sufficiently to detect hazards, with the same devastating consequences.

Almost all drivers have experienced what has become known as highway hypnosis, or time-gap experiences. This is the experience of suddenly become alert when driving after having ‘drifted off’ for a period of time. Time gap experiences have been associated with lower hit rates to unexpected events when driving, and slower reaction times (Chapman, Ismail & Underwood, 1999).. The Psychological explanation for this phenomenon is that when attention is sufficiently under-engaged, the brain ‘switches-off’ from the primary task. This under-engagement can occur in the driving situation as a consequence of combining a highly automatic task such as driving, with an unvarying environment. This attentional under-load, is clearly as important to the driving situation as attentional overload.

A model of attentional load in driving

The cognitive load theory of distraction suggests that there is a linear negative relationship between increasing distraction and decreasing attention to a primary task such as driving. This is consistent with our intuitive notion of driving becoming harder as distractions increases, and it is entirely consistent with the cognitive literature. This is represented in Figure 1

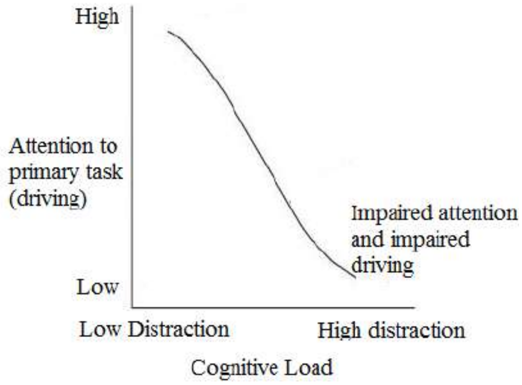

Figure 1. The negative relationship between distraction and driving when distraction is high

However, under-load in driving or any task requiring sustained attention, can be equally detrimental, with a similar linear relationship that is the reverse of the one above. In this case, there is a proposed linear positive relationship between attention and driving, such that attention for a primary task such as driving, decreases as cognitive load (and hence attentional engagement) decreases. Refer to Figure 2

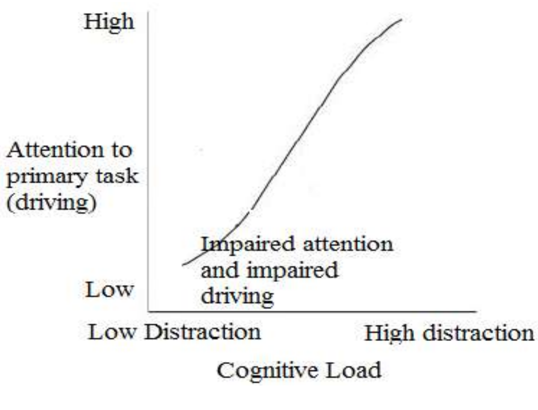

Figure 2. The positive relationship between distraction and driving when distraction is low

One possible interpretation of this, is a model of attention which suggests that our ability to detect unexpected events is at peak performance when there is a certain amount of distraction in the environment, somewhere between under-engaged, but before cognitive load starts to deteriorate performance. This is consistent with the intuitive recognition that when drivers ‘drift off’, their common response is to turn on the radio to ‘wake themselves up”. Thus a ‘healthy’ level of distraction is likely to increase a driver’s awareness of additional objects and hazards, but in addition to this also increase performance on the primary task of driving. Refer to Figure 3

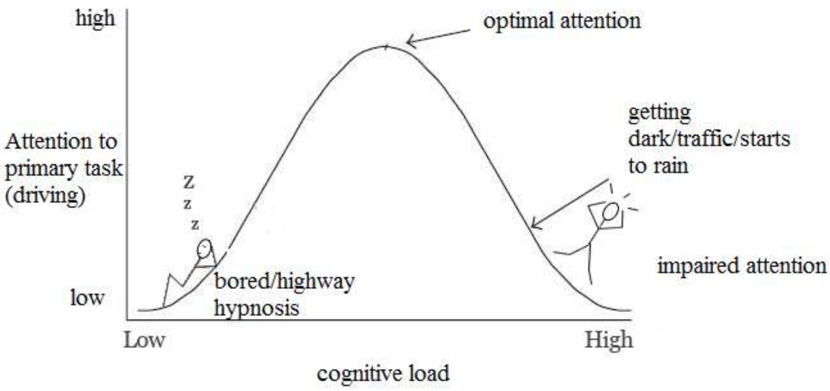

Figure 3. The inverted-U shaped relationship between distraction and driving, from low to high levels of distraction

Models for the relationship between attention and cognitive load

The model in Figure 3 is consistent with the well-known relationship between stress and performance. The relationship was first described by Yerkes and Dodson (1908) in the context of animal learning. They demonstrated that there was an inverted-U relationship between learning to discriminate between two stimuli, and the intensity of electric shocks delivered for punishment when the animal got the discrimination incorrect. This model was subsequently adopted to reflect the inverted-U relationship between arousal and performance. In this model, performance on a dependent variable is lowest when arousal is low, increases to an optimal level with moderate levels of arousal, and then decreases again as arousal increases.

The parallels between the Yerkes-Dodson law and the one proposed here are clear. Indeed, one could conceptualise the inverted-U model proposed here as being a variant on the Yerkes-Dodson law. This is important because it then has the value of psychological parsimony in terms of theory and physiology, cleanly explaining both cognitive load and cognitive under-engagement into a single model. This allows the derivation of testable hypotheses and predictions. It also has the value of biological parsimony. There are other theories that have been submitted to explain decreases in performance when under-engaged, particularly in the driving context (e.g., Young & Stanton, 2002), however, it is more biologically plausible that models of behaviour are ubiquitous across physiological systems; if it works for arousal, it makes sense that it should also work for attention. Thus attention for a primary task such as driving, is likely to be optimal when there is a little bit of distraction to engage attention. Indeed, recent findings in our lab suggest that some types of distraction may increase attention for performance on a primary task (Beanland et al, 2001; Beanland, et al, 2010).

The notion of under engagement resulting in poor attentional performance has been considered in the human factors literature for some time (e.g., Frankman & Adams, 1962) under behavioural concepts of vigilance, fatigue, monitoring, and so on. The notion of 'cognitive engagement' in the current paper may also be akin to the notion of 'Motivation intensity' elsewhere (Brehm & Self, 1989) or 'vigilance' in some instances (refer to Warm, Parasuraman, Mason & Matthews, 2008 for a review). Within this literature, there is some contention regarding the aetiology of vigilance decline – the situation where vigilance decreases over time. It has been suggested that vigilance is effortful and stressful, becoming more so over time (e.g. Warm, Dember & Hancock, 1996). This is certainly the case. However, stressful is not the same thing as cognitively demanding in terms of cognitive load. Elevated levels of catecholamines during vigilance tasks speak to this possibility (Frankenhaeuser, Nordheden, Myrsten, & Post, 1971), but could equally reflect the mean response over time to the stress associated with having 'drifted off'.

Indeed, that linear decreases in cerebral blood volume commensurate with decreases in vigilance, as is increase in frontal alpha signals (Kamzanova, Kustubayeva & Matthews, 2014) (increasing power in alpha reflects decreasing alertness), is consistent with progressive decreases in cognitive engagement (although it should be noted that Kamzanova et al, argue against this conclusion). Similarly, a subtle understanding of the notion of fatigue is such that it could reflect commitment of effort to complete a task, not engagement in the task itself (Earle, Hockey, Earle & Clough, 2015). However, evidence that lane maintenance can get better with some degree of cognitive distraction (e.g., Medeiros-Ward, Cooper & Strayer, 2013), is consistent with the notion of 'healthy distraction. Suffice to say that there remains considerable debate around the existence and understanding of the left side of the curve in Figure 3 here.

Our research

The driving situation is one which requires constant monitoring of the visual environment and continuous filtering of visual information in order to attend to the most important cues. In many cases however, we fail to see something of critical importance when driving. Looked-but-failed-to-see crashes (Hills, 1980; Treat 1980), have been implicated as the third most frequent type of driver error (Brown, 2005). Cognitively, the looked-but-failed-to-see experience maps precisely onto a known psychological phenomenon called Inattentional Blindness (IB). In IB, an observer fails to see an unexpected stimulus or event while attending to another, primary task (Mack & Rock, 1998; Beanland, Allen & Pammer 2011; Koivisto & Revunsuo, 2008). IB is closely related to hazard detection when driving (White & Caird, 2010), and thus provides a sound experimental framework with which to study this issue.

We have conducted a number of experiments using IB demonstrating that attention for the unexpected object increases with some types of distraction. The basic task paradigm involves requiring participants to track multiple objects around a computer screen for trials of 15-40 seconds each - all trials ran for the same length of time in any one experiment, the different times here (15-40sec) reflect experimental manipulations between experiments. The participant is required at the end of each trial to indicate how many objects 'bounced' off the edge of the screen. For example, the participant may be required to track the black objects, ignoring the white, keeping a silent tally of how many times they 'hit' or 'bounce' off the edge of the screen. After a certain number of trials, a critical trial occurs in which an additional unexpected object appears. At the end of the critical

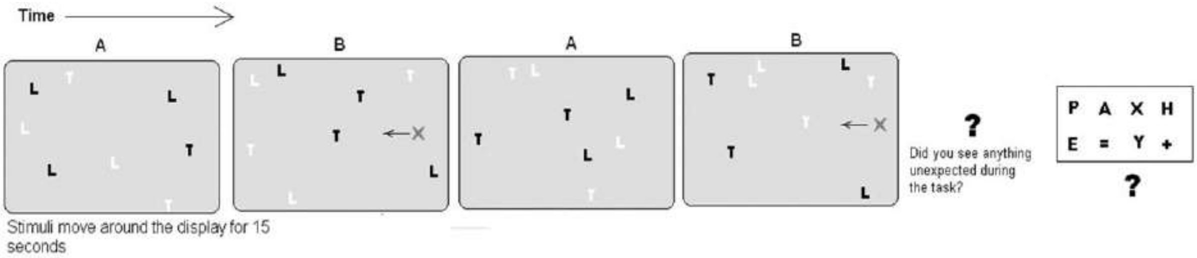

Figure 4. The standard IB 'bounce' task used in our lab to measure detection of the unexpected object. Primary task performance is based on how well the participant tracks the letters as they move around and 'bounce' off the edge of the computer screen.

trial, the participant is asked if they had seen anything other than the shapes they were to be tracking. Participants who noticed the unexpected object are asked to describe it and point it out from a selection sheet of plausible alternatives. Participants who did not notice it are nevertheless asked to "make a guess" as to which object might have appeared on the screen. The dependent variable is whether the participant reports seeing the unexpected object or not. Refer to Figure 4, and the following references for more detailed descriptions of the relevant methodologies

(Beanland, Allen & Pammer, 2011; Pammer, Korrell & Bell, 2015). Each experiment of this type typically takes less than 10 minutes to run.

Using this, and similar IB tasks, we have demonstrated a consistent finding; low levels of visual or auditory distraction appear to increase noticing of the unexpected object, typically with no additional effect on primary task performance (tracking the bouncing objects). The first studies in this area were student projects (e.g., Beanland, Pammer & Colton, 2010). In the first of these, participants performed the above IB task while simultaneously exposed to one of three types of audio stimuli: music (with or without lyrics Beanland, Allen & Pammer 2011; Koivisto & Revunsuo, 2008), speech, no audio and general background noise (café sounds). Consistent with load theory, our initial hypotheses were that rates of noticing in IB would decrease with increasing distraction. In fact what we found was the opposite effect. Rates of noticing got better with concurrent music and then even better with concurrent language (refer to Figure 5).

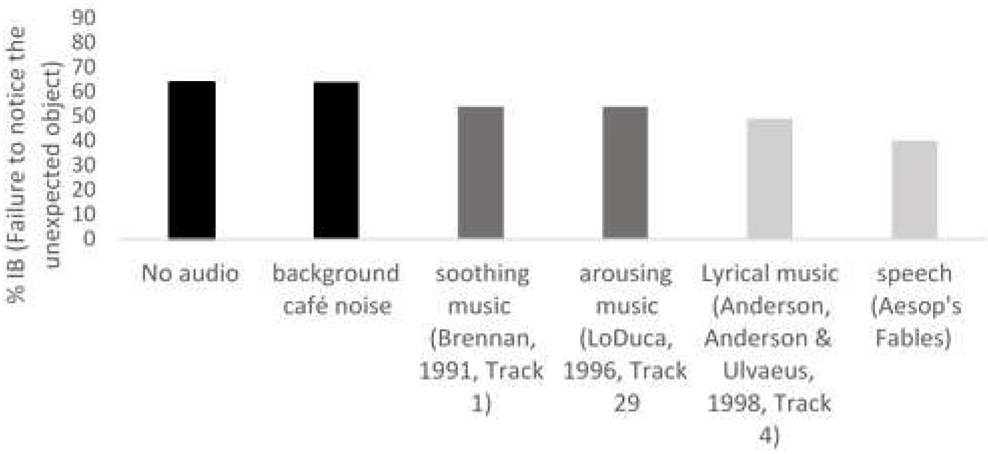

Figure 5. Rates of IB when different types of auditory distractors were played concurrently via headphones while the participant was doing the task (adapted from Beanland et al, 2010)

Overall, 62% of participants in the no-audio condition experienced IB, compared to participants who listened to language where 56% noticed the unexpected object, $\chi^2(1, N = 34) = 4.9, p = 0.27$, and the instrumental conditions where 47% noticed the unexpected object (this was not significantly different from the control conditions). This finding prompted us to explore this effect more systematically.

In Beanland, Allen and Pammer, (2011), participants performed the standard IB task and we systematically varied cognitive load and concurrent auditory stimuli to determine if the change in rates of IB could be due to effects of cognitive load. In this case, load was manipulated by changing the speed of the tracked objects from fast (high load) to slow (low load). Similarly, the audio stimuli – in this case well-known lyrical music – was either presented actively, where the participant was to listen for tones within the music while performing the IB bounce task, or passively, where participants were simply asked to listen to the concurrent music.

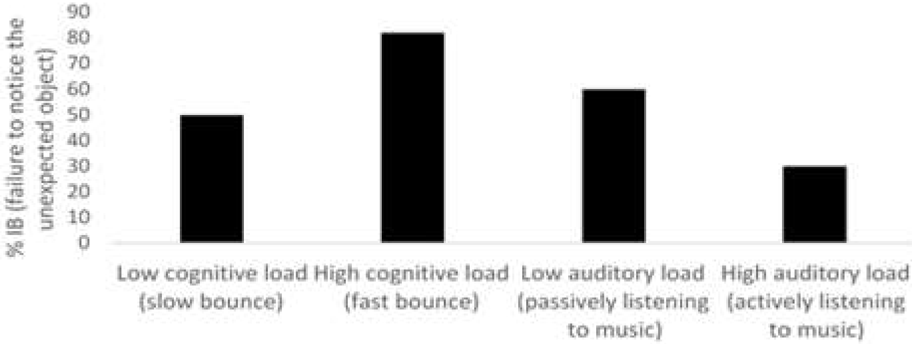

Figure 6. Rates of IB when auditory distractors were varied with cognitive load (adapted from Beanland et al, 2011)

Overall 54% of participants experienced IB, with rates of IB varying significantly across conditions, χ^2 (3, N = 100) = 13.69, p = .003. Compared to low cognitive load (52% IB), IB was significantly higher under high cognitive load (80% IB), χ^2 (1, N = 25) = 7.85, p = .005. Conversely, participants under high auditory load exhibited significantly lower IB rates (28% IB), χ^2 (1, N = 25) = 5.77, p = .016, compared to the low visual load condition. There was no difference between low visual load and low auditory load (56% IB), χ^2 (1, N = 25) = 0.16, p = .689. Thus, as expected, the high cognitive load task had the highest rates of IB (lowest rates of noticing), however the lowest rates of IB (highest rates of noticing) was when participants were actively listening to the music while performing the IB task.

The finding that attention for an unexpected object in an IB task increases with auditory distraction, has been replicated using visual distraction. In Pammer, Korrell and Bell, (2015) participants did the IB bounce task in which was embedded a transient screen 'flicker' that occurred for two frames. The distractor flicker was explained to participants at the end of the

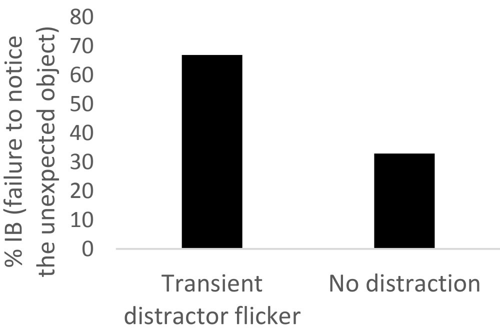

Figure 7. Rates of IB with transient visual distraction in the form of a screen flicker (adapted from Pammer et al, 2015)

experiment as an irritating 'glitch' in the program. It was however carefully constructed to appear at specific points in the experiment, including at the start of the critical trial. Consistent with the auditory distractin studies, the presence of unrelated, transient screen flicker halved the rates of IB. Refer to Figure 7, χ^2 (1, N= 121) =10.118, p =.001, Φ=.306. Even more interestingly, rates of IB remained the same irrespective of whether participants noticed the flicker distraction.

We have also demonstrated an increase in visual attention using tasks other than IB. In Attentional Blink (AB), a sequence of stimuli such as numbers and letters flash up rapidly, one after the other, spatially superimposed to form a RSVP (Rapid Serial Visual Presentation) sequence. The dependent variable is the ability to detect two targets (T1 and T2), embedded one after the other in the sequence. Participants are able to see the first letter with relative ease, but often miss seeing the second letter if it appears within a 100-500 millisecond window of the first letter (Shapiro, Arnell & Raymond, 1997). A number of studies have demonstrated that when participants engage in an AB task with an associated distractor, the 'blink' in attention is significantly reduced (i.e., attention gets better for the second target). For example, Arend, Johnston and Shapiro (2006) found that participants were more likely to notice the T2 when an irrelevant 'star-field' pattern of dots were presented around the borders of the display. Similarly, Olivers and Nieuwenhuis (2005) found that the Attentional Blink was significantly reduced in conditions which had a distracting task (such as thinking about a recent holiday or listening to music) compared to a control condition. We have replicated these findings, demonstrating that the Target 2 becomes easier to see at the point of maximum masking when surrounded by a concurrent visual distractor $F(3, 20) = 6.46$, $p = .003$, partial $\eta^2 = .48$, refer to Figure 8.

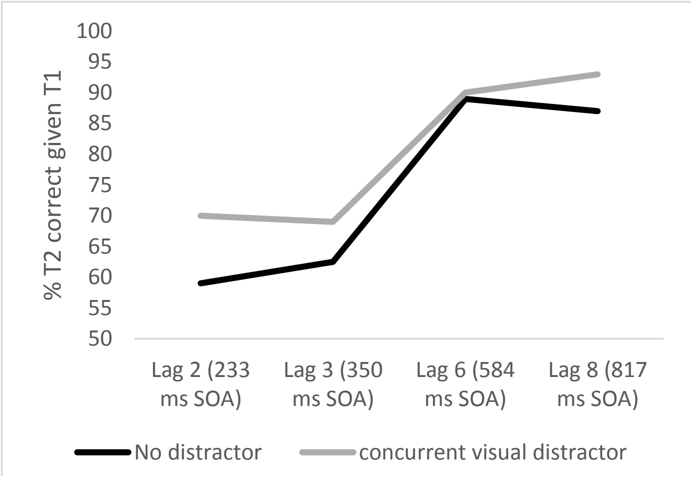

Figure 8. Decrease in masking in an AB task when the stimuli are presented with a surrounding visual distractor (adapted from Carter & Pammer, 2009 [unpublished honours thesis])

Limitations and future directions

The collective result from this series of studies is that using basic tests of attentional selection such as IB and AB, suggest that participants' ability to detect a target improves if the task is accompanied by some unrelated auditory or visual distraction. This has important implications for attention in driving. The attention tasks that we have used here are good correlates of attentional mechanisms that are used when driving, for example both require monitoring multiple moving objects. However the task still remains a highly simplified version of the driving experience. Recently we designed a novel IB task in which participants made driving judgments that were pertinent to typical driving scenarios, we measured IB as whether they detected an unexpected object in each scenario. The unexpected object has been a relevant object on the side of the road such as a child, a dog or a garbage bin (Pammer, Bairnsfather, Burns & Hellsing, 2015), a motorcycle (Sabadas & Pammer, *under review*), or unexpected objects like a kangaroo in a city driving scene or a man in a business suit in a rural driving scene (Pammer & Blink, 2013). These tasks provide a strong theoretical link between cognitive tests of attention, and the applied experience of driving. We are currently conducting the distraction studies with these driving-IB tasks. We predict that transient auditory distraction will increase detection of an unexpected object in a driving-IB task, just as we have demonstrated in standard cognitive-IB tasks. In another study, we are explicitly exploring the nature of this inverted-U; the relationship between driving and attentional allocation. Here participants will be driving in a simulator while singing along to their favourite music. We will systematically vary the driving and singing environments to monitor the relationship between spontaneous singing (distraction) and difficulty in the driving environment.

Specific questions and objectives

The overarching aim of this research path is to understand the role of high and low levels of distraction in IB, and hazard detection when driving. We anticipate that while there is a point at which driver distraction impedes attentional performance, we also believe that there is in fact a 'healthy' level of distraction is necessary to maintain optimal driving performance. Within this, specific sub-goals and questions include the following:

- Can we describe the idiosyncratic nature of driver distraction: We anticipate that not everyone is created equal when it comes to distraction. Similar to the observation that some people need to work or study while listening to the radio while others require complete silence, what are the parameters at an individual level to determine how 'healthy-distraction' varies between people?
- Can we develop a psychological understanding of the consequences of driver distraction on IB and hazard detection?
- Does the notion of distraction change in highly trained drivers? We have developed contacts over the last 2 years with the Australian Federal Police and state ambulance services to explore the role of increased distraction and hazard perception in highly experienced drivers.
- What is the connection between distraction and automaticity? Generally, driving is familiar and automatic, requiring little cognitive input. We speculate that it is the aspect of automaticity in driving that makes it particularly susceptible to highway-hypnosis, and then IB and poor hazard detection as a consequence.
- Does sub-optimal attentional engagement also result in poor performance on the primary tasks – in this case the physical act of driving? Thus, healthy distraction might not only increase vigilance to hazards, but also improve task specific driving behavior.
- Can this research provide a theoretical framework for the development of in-car technology? The results would provide a rationale for in-car features designed to help the driver focus. However, findings may also provide basis for a debate regarding the use of cruise-control and other assistive in-car technology. Making the driving situation easier is unlikely to result in better driver behavior.

Conclusions

A driver 'drifts off', veering dangerously into the shoulder of the road. Shaken, he turns on the radio to help him focus. Attention, and our ability to detect unexpected events appears to be at peak performance when there is a certain amount of distraction in the environment, somewhere between under-engaged, but before cognitive load starts to deteriorate performance. The question of interest, is why does attention decrease when distraction is low? Logic would suggest that when the brain has little else to do, that it would be more likely to detect unexpected events, however our results indicate that this is not the case. Answering this question will allow us to determine how we can keep attention at optimal levels in the driving environment. Thus a 'healthy' level of distraction is likely to increase a driver's awareness of additional objects and hazards, but in addition to this also increase performance on the primary task of driving, and suggesting that some distraction is vital for safe driving.

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The MUARC-TAC Enhanced Crash Investigation Study: Using Event Data Recorders and Simulated Crash Reconstructions in the Analysis of Crash Causation

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Background

Road crashes represent an immense cost in social, personal and economic terms. Since its establishment in 1987, the Transport Accident Commission (TAC) has been responsible for providing care and rehabilitation to individuals injured on Victorian roads. In recognition of the magnitude of serious injury crashes, the TAC commissioned the Monash University Accident Research Centre (MUARC) to establish the Enhanced Crash Investigation Study (ECIS). The ECIS study aims to investigate the causes and consequences of 400 serious injury crashes involving passenger vehicles. The program objective includes informing the development of road safety programs and countermeasures by providing a comprehensive understanding of crash causation and injury severity. To date, MUARC has investigated and analysed over 100 real-world crashes via a case-by-case systems failure analysis and identified multiple policy options based on ‘best practice’ prevention.

Crashes of specific interest are simulated using crash reconstruction software (Human Vehicle and Environment (HVE, V11.01). The process of crash reconstruction permits a deeper understanding of factors and driver behaviours that could have contributed to the severity of the crash. While a simulated crash is validated against the narrative of the crash and damage measures such as the Collision Deformation Classification (CDC), change in velocity (delta-V), principal direction of force and crush measurements (determined from vehicle inspections), generating the simulation involves various driver controls being assumed, including reaction times and braking rate, steering and throttle position, yaw rate and the deceleration of the vehicle upon impact. These assumptions, in turn, limits the simulation’s outcome in understanding driver behaviour and vehicle kinematics both pre-crash, during-crash and post-crash.

An Event Data Recorder (EDR) is a device installed in a motor vehicle to record technical vehicle and occupant information for a brief period of time before, during and after a crash. The primary purpose of EDRs is to permit an assessment of vehicle safety system performance. The USA’s National Highway Traffic Safety Administration (NHTSA) has issued a regulation (49 CFR Part 563) requiring that vehicles manufactured on or after September 1, 2012 that are voluntarily equipped with EDRs must record 15 data elements at a minimum in a standardized format, such as 5s of pre-crash speed, engine throttle and braking and also 250ms of longitudinal delta-V after the initial impact. Most vehicle EDRs capture data during a frontal collision, typically those causing visible damage to the vehicle (NHTSA, 2006). EDR data has been previously used to study driver behaviour and vehicle performance during real-world crashes (Kusano and Gabler 2011, Kusano and Gabler 2013, Iraeus and Lindquist 2014, Johnson and Gabler 2014, Su, Liu et al. 2014).

The aim of this study was to examine the feasibility of performing full crash reconstructions using two ECIS cases for which EDR data had been downloaded from the vehicles. Using the EDR data in the crash simulation, it was to be determined whether modifying certain parameters, such as braking, throttle and initial speed, would have made a difference to the outcome of the crash. By applying the crash pulses from two separate real-world impacts to two crashes reconstructed in the simulated environment, this paper aims to determine if the integration and use of EDR data could improve the accuracy of the crash simulations. This in turn bears on the level of confidence that can be had with regard to contributing factors and crash avoidance and injury severity countermeasures.

Method

Participant drivers were recruited into the ECIS study following admission to The Alfred hospital, one of the two adult trauma centres in Victoria. Participants provide informed consent that permits the collection of a detailed description of all injuries sustained, ambulance notes and medical records. Participants also undertake an interview and provide consent for their vehicle to be inspected. EDR data is collected during the vehicle inspection. MUARC crash investigators also document the level of deformation and intrusion, impact severity and potential pre- and post-impact vehicle factors which may have contributed towards the crash outcomes.

The EDR data downloaded from two real-world case vehicles were integrated within HVE simulation software. Data were applied to the Centre of Gravity (CG) of two simulation vehicles so that pre-, during- and post-crash kinematics could be studied. Given the application of a crash pulse to a vehicles CG will only provide the CG trajectory and not necessarily result in the post-crash angular orientation of a vehicle, the vehicles' trajectories upon application of the EDR data was validated against the case narrative and physical data, as well as velocity (for one case) and yaw rate (for the second case) from the simulation package. Three variables were then varied to determine when the raw crash pulse would take effect, and from this, determine if the crash could have been avoided; these three parameters being 1) applying a driver reaction of 375N brake force one second before the crash pulse; 2) reducing the driver's initial speed by 5km/h; and 3) reducing road friction to 0.5.

Results

Case 1: A 2012 Mazda3 hatchback, the case vehicle, ran a red light in a 70km/h zone and collided with a 1995 Holden Commodore that was turning right.

Case 2: A 2013 Toyota Aurion sedan, the case vehicle, failed to give way trying to cross to the opposite side of the road and was struck on the driver's side by a 2013 Toyota Corolla that was continuing straight on the road.

Real-world evidence from the vehicle and scene inspections show the probable paths taken by the case vehicles before they came to rest (Figure 1), where point of impact (POI) and point of rest (POR) are shown for the case vehicles. The B vehicles were unavailable for inspection and no EDR data was obtained.

Figure 1. Scene diagrams show the probable paths taken by the case vehicles (green) in Case 1 (left) and Case 2 (right), showing the POI and POR. The B (non-case) vehicle is shown in red.

Case 1: The case vehicle's EDR data reports a two event collision with approximately 2.5s between events. Scene and vehicle inspections indicate that the second event was possibly triggered when the case vehicle hit a curb. Since the 2012 Mazda3 was not represented in HVE's vehicle database, a Honda Civic (1992-1995) was used to represent the case vehicle in the simulation. The vehicles weight was adjusted to represent the Mazda with the occupant (1366kg). The EDR data, including initial speed, lateral and longitudinal delta-V, pre-impact throttle from events one and two were entered into HVE to simulate the kinematics of the Mazda3 after the first event was triggered. Yaw data and steering data were not available.

Case 2: EDR data reports a single impact event. The 2013 Toyota Aurion was not available in the HVE database, hence a Toyota Camry LE (2007-2011) was chosen to represent the case vehicle with weight adjusted to match the real-world vehicle plus occupant (1610kg). This was an advanced EDR module and provided a greater number of outputs compared to the EDR from the Mazda. The longitudinal forces (pre-impact) and lateral forces (impact and post impact) were entered into HVE, along with initial speed, steering input and throttle. Forces were calculated by computing the vehicles acceleration from the EDRs delta-V output and multiplying the data by the vehicles kerb mass. Figure 2 shows the crash pulses applied to the two representative vehicles over the duration of the crash.

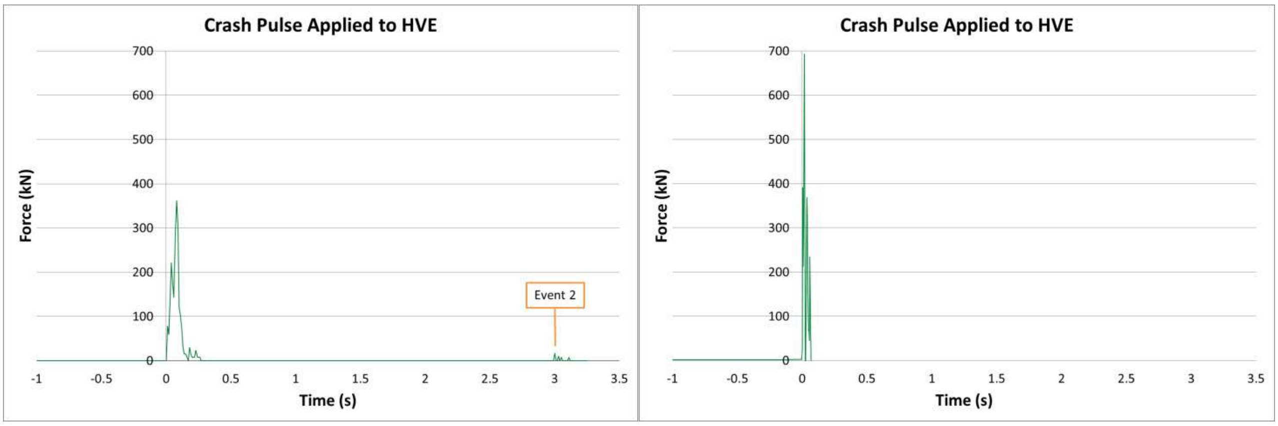

Figure 2. The crash pulses from Case 1 (left) and Case 2 (right) showing the magnitude of forces during the impact. Note that crash pulses were zero from t= -5 to t=0s in case 1 and small (i.e under 3kN) from t=-4.75 to t = 0s in case 2 but does not appear on the graphs due to the large force scale.

Case 1: Upon application of the crash pulse, the case vehicle was pushed laterally but continued without much rotation in the Z-plane given no steering data or yaw data was entered into HVE. To validate the EDR application in HVE, an output of the vehicle velocity over the duration of the crash pulse from HVE was compared to the velocity recorded on the EDR (given that no yaw data was available).

Case 2: The case vehicles trajectory upon application of the crash pulse appeared reasonable. Initial velocity and throttle and steering over the duration of the crash pulse were applied to the simulation vehicle. The yaw rate (output from HVE) was used to validate the application of the crash pulse given the EDR also recorded yaw rate. Figure 3 compares the EDR with HVE data.

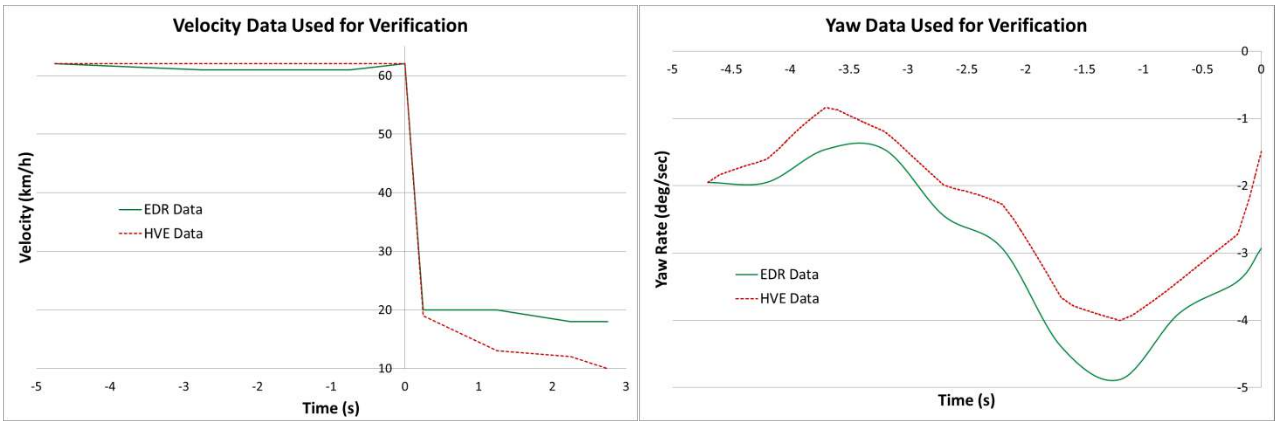

Figure 3**. **Pre-impact velocity data and yaw data from the EDR was compared to the outputs from HVE to validate Case 1 (left) and Case 2 (right) respectively. Note that time at zero seconds is the event trigger.

The same crash was then simulated with the EDR data and (estimated) steering applied beyond the crash pulse until the final resting position of the simulation vehicles matched that of the real-world crash (verified by physical evidence). No driver inputs other than steering were applied. The trajectories of the vehicles with only EDR/crash pulse data applied and EDR/crash pulse data and steering applied are shown in Figure 4, overlaying each other to demonstrate the limitation of using EDR output alone to reconstruct the two crashes. The simulations of the impacts with EDR/crash pulse data and steering inputs applied were used here forth.

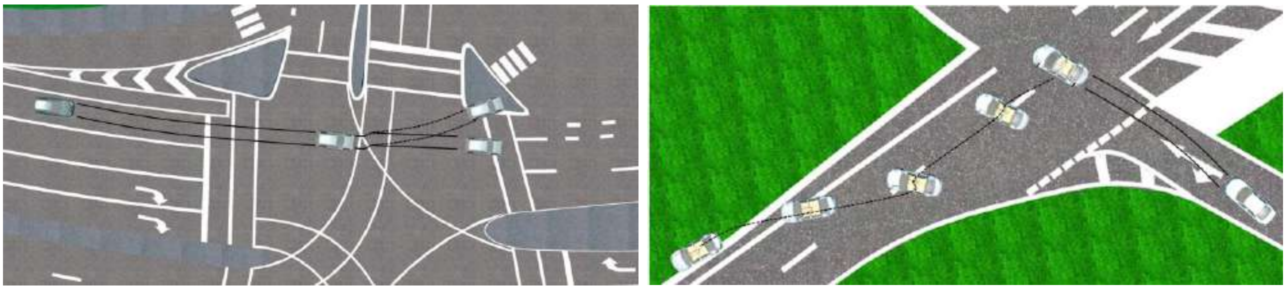

Figure 4**. **Images showing the vehicles at the starting position that the crash pulse was applied, the point of impact and following the application of EDR data alone (solid lines) vs. EDR data plus approximated steering (dotted line) for case 1 (left) and case 2 (right). The solid line showing the path the car takes with EDR data alone in Case 2, is barely visible given the 68ms of crash pulse that was available.

The following variables were applied to the Mazda (Case 1) and Toyota (Case 2) to determine if there would be a notable difference in outcome to the crash: braking (375N) was applied one second before the EDR was triggered (crash event, t=0s); driver velocity (initial) was reduced by 5km/h (from 62km/h to 57km/h for the Mazda and from 22km/h to 17km/h for the Toyota; and road friction was changed from 1.0 to 0.5. Panicked braking of 0.5G (applied by a 75kg driver) was assumed, hence of 375N was applied in the simulations to model panicked braking. Using the simulation, the vehicles' distance to the point of impact is shown in the table below (where '-'ve values indicate a distance which the vehicle stops before the original point of impact, a '+'ve value indicates a distance past the original point of impact).

Table 1. The distance to/from the point of impact when parameters are altered in a crash scenario. The point measured is to/from the right front tyre.

	Case 1		**Case 2**	
Scenario	**Approximate distance to/from original point of impact**	**Probable outcome**	**Approximate distance to/from original point of impact**	**Probable outcome**
Original case	0m	Impact	0m	Impact
Braking applied (375N, 1s before collision)	-4.5m	Impact avoided	-3.0m	Most likely impact avoided
Reduced speed (57km/h for Mazda, 17km/h for Toyota)	-2.5m	Impact avoided	-4.8m	Impact avoided
Reduced road friction (0.5)	+ 1.3m	Impact (positioned at driver side door)	+0.4m	Impact

The simulations demonstrated that, when applying brakes (375N) prior to impact and reducing speed, the two crashes could have been avoided. Reducing road friction was shown to have little effect on impact point, possibly making the impact more severe in both cases as the car would have travelled further into the path of the oncoming vehicles.

Discussion

Data downloaded from EDR modules provide valuable pre- and during-crash measures which support case narratives determined from arduously collected real-world crash data. Depending on the EDR module, it can provide basic crash measures (Case 1) or multiple outputs including yaw, steering and throttle position for the crash (Case 2). Independent of the variables recorded, EDR data in the cases studied only provided 250ms of during-crash data from which driver reactions could be studied. Using simulation software, it was shown that the 250ms of during-crash data captured by the EDRs provide limited information regarding vehicle trajectories or driver inputs over the duration of the entire crash. Should EDR data capture 5 seconds of data post-crash as it does pre-crash, this will limit the driver input assumptions required in the reconstruction, resulting in more accurate determination of causal factors and crash outcomes. It is noteworthy that previous research has demonstrated that EDRs underestimate lateral delta-V by up to 4km/h (Tsoi, Johnson & Gabler, 2014). This underestimation of the delta-V may have contributed to the inaccuracy of the reconstruction rest position compared to real-world evidence.

Simulation software provides the opportunity to easily visualise the effects of forces when experimenting with real-world and EDR data, including the effects of braking, steering, speed or environmental factors on impact scenarios. The variables adjusted in the simulations here (braking application, reduced speed and reduced friction), were mainly used to validate the car's behaviour to driver inputs while the EDR data was used as a marker of impact. Our simulations showed that even extremely light braking (375 N) could have prevented the crash. This suggests that the drivers were likely completely unaware of the impending crash. Despite the limitations of EDR data and the simulation software, this study demonstrates the value of using EDR data and crash reconstruction techniques in combination with real-world data to determine crash causation and assist in developing countermeasures that could see a reduction in road trauma.

Implications

This paper presents a comprehensive and robust method for integrating real-world data and EDR data in combination with simulation software. This represents a valuable means of identifying and investigating relevant and effective countermeasure options related to crash causation, including the potential impact of alternative braking scenarios and lower pre-crash speed. The value of this information is that it can assist in the prioritisation of road safety countermeasures and policies.

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Older road user safety – identifying needs and gaps in health professionals' communications with older patients about fitness to drive

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Abstract

Health professionals have an important role to play in assessing and advising their patients about fitness to drive. This is important for all drivers, but especially older drivers.

The aims of this exploratory research were to:

- determine what health professionals currently know about older drivers' fitness to drive and road safety;
- identify any gaps in health professionals' knowledge;
- determine the most effective ways of informing or educating health professionals about fitness to drive and how to provide the best advice to their older patients.

A range of consultations, focus groups and qualitative surveys were undertaken with Victorian GPs, optometrists, occupational therapists and other health professionals.

The research showed that the take up of existing training or education opportunities was generally low, especially among GPs. Raising the awareness among health professionals about their key responsibilities, the main conditions that can affect driving and how to assess fitness to drive were identified as key needs. Several recommendations to improve the communication with health professionals were identified, including easy to use resources, plus improved education and professional development.

Introduction

The ageing population means that more older people will be driving than ever before. As ageing can be associated with a range of health declines and disorders, the extent and nature of communications from health professionals with older people about fitness to drive is important.

Ensuring that health professionals have appropriate information, knowledge and motivation to engage with older road users about their fitness to drive is likely to impact on the road safety outcomes of ageing road users.

VicRoads undertook a project to explore the information needs of health professionals and the best methods of effectively communicating with then. The overall aim of the project was to determine how to assist and support health professionals to evaluate fitness to drive and communicate key messages to older patients.

The key research questions addressed were:

a) Who are the key health professionals to be targeted through the proposed strategy?
b) What road safety information and knowledge is needed by each target group?
c) What information do the target groups currently use or access and how useful is this information?

d) What communication mechanisms and approaches would be most used by the target groups?
e) What key messages will be the most appropriate and effective?

Methodology

Data for this project was collected via consultations, in depth interviews, two qualitative surveys and a small focus group.

Consultation with health professional representative groups

Consultations with a number of health professional representative groups were conducted. The aim of the consultations was to learn from each representative group about their members:

- level of knowledge
- how they access information
- issues faced in completing medical and eyesight assessments
- what communication mechanisms and tools would be most effective
- how to efficiently deliver information
- what key messages are likely to be most effective/useful.

To achieve this, meetings were held with the peak representative bodies for the most relevant health professional groups. Consultations were held with the Victorian chapters or branches of the following organisations:

- Royal Australian College of General Practitioners (RACGP)
- Australia and New Zealand Society of Geriatric Medicine (ANZSGM)
- Optometry Association of Australia (OAA)
- Royal Australian and New Zealand College of Ophthalmologists (RANZCO)
- Occupational Therapy Australia (OTA)
- Royal Australian College of Surgeons (RACS)
- Networking Health Victoria
- Practice Nurse Association
- Victorian Institute of Forensic Medicine (VIFM)

In addition, consultations were held with some organisations that support individuals who have diseases that can impair driving. These organisations included:

- Alzheimer's Australia Victoria
- Diabetes Australia Victoria
- Australian Diabetes Educators Association
- Heart Foundation Victoria

Interviews and discussions with health professionals

With the assistance of the peak bodies, some further information was gathered from practising health professionals to gain a broader range of views and feedback on the key research questions.

Consultations with five general practitioners (GPs) were undertaken. Two in depth interviews were conducted with experienced GPs working in rural Victoria who were also board members of

RACGP. In addition, a small discussion group involving three GPs working in the metropolitan area was conducted.

An online survey of optometrists was conducted in October 2014, with the assistance of the Optometry Association of Victoria. A total of 21 survey responses was received. An online survey of occupational therapists was undertaken with the assistance of Occupational Therapy Australia Victoria. A total of 16 responses was received.

Key Findings

a. Health professional groups to target

The primary groups of health professionals involved in the process of assessing and reporting on a person's fitness to drive are GPs. In addition, optometrists are often required to complete eyesight report forms, as are ophthalmologists, who primarily care for patients with eye diseases. All practising GPs, ophthalmologists and optometrists are regularly required to undertake these assessments and complete reports for people wishing to hold a driver licence, as well as those needing assessments for special licences such as heavy vehicle and taxi licences. These groups of health professionals were regarded as the key groups to target.

Some specialists physicians are also involved in assessing fitness to drive, but to a lesser extent. One group of specialists is geriatricians, who usual work in hospitals and may see older patients who require additional care for ongoing or complex health conditions. Surgeons are also required to advise patients about fitness to drive, especially after surgery. Neurologists are usually involved in the care of people with dementia, stroke or epilepsy. Endocrinologists care for people with diabetes and cardiologists care for people who experience heart related diseases or conditions. All of these conditions can affect a person's fitness to drive so health professionals working in these fields should also be targeted.

Occupational therapists also play a large role. Many occupational therapists (OTs) work in aged care and may be involved in caring for older patients who have a range of conditions that may impact on their driving. While OTs who are not specifically trained to undertake driving assessments do not have a formal role in completing driving assessments or medical reports, they often play a role in advising patients and their families about fitness to drive, and can work with other health professionals if they are concerned that a person is not fit to drive.

A range of allied health professionals currently play a role in discussing driving safety with patients and may potentially increase this role if some additional resources and training were provided. Practice nurses who work in medical practices were regarded as a group who could potentially play a larger role in the future, especially in providing information and support to patients who may need to make the transition from driving to non-driving. In addition, diabetes educators, community nurses and those people conducting cardiac and stroke rehabilitation may also potentially play an important communication role with older drivers in the future.

b. Information needs of health professional groups

There were some similarities in the information needed by varying health professional groups. In general, information about how the medical review process works, the responsibilities of health professionals and how to assist patients who need to stop driving were consistent themes across all health professional groups. Most health professionals were aware of the Assessing Fitness to Drive (AFTD) Guidelines (Austroads and National Transport Commission, 2012). However, beyond this, very little other education, training or resources were utilised by any of the health professional groups consulted, with the exception of occupational therapists, who were generally quite engaged and informed about fitness to drive.

GPs, geriatricians and specialists

Overall, GPs as well as geriatricians and other medical specialists need to know about:

- the key conditions that can impair safe driving
- how to advise someone about their future driving safety
- what their legal and ethical obligations are
- how to assess patients who require medical reports
- to use the AFTD guidelines (the latest version) when assessing patients
- to consider a patient's fitness to drive at every diagnosis and monitor and discuss driving safety regularly with patients
- to warn patients if they have a progressive condition that may mean they will need to stop driving in the future
- what to advise patients about driving after significant health events (such as stroke or heart conditions), surgery and diagnosis of a "reportable" condition (such as dementia or diabetes).

All of the GPs consulted completed medical driving assessments for patients on a semi-regular basis. Most were aware to some extent of the AFTD guidelines, but were not necessarily using the latest version. In general the AFTD guidelines were regarded as difficult to use by GPs and time-consuming to navigate. There is a risk that these difficulties may lead to the guidelines not being used correctly.

Beyond being aware of the need to discuss driving with patients who had experienced a significant health event (such as a stroke or heart attack) or had a recent diagnosis (such as epilepsy, diabetes or dementia), most GPs were not proactive in discussing fitness to drive with their patients. Nor did many GPs seemed to be willing to report a person who might be unfit to drive to VicRoads.

None of the specialists or GPs consulted for this project had undertaken any training, attended any seminars or undertaken any further reading or research on the area of fitness to drive, with the exception of one GP who had attended a VicRoads seminar approximately 10 years ago.

Most learnt about fitness to drive from other professionals, from reading the AFTD guidelines and possibly when they were a GP registrar.

Ophthalmologists and optometrists

Optometrists and ophthalmologists are all quite aware of the required visual standards for driving. Most felt it was very clear, it is written on the back of the eyesight assessment and is easy to measure. The issues that do arise for eye specialists are:

- using the latest version of the AFTD guidelines
- understanding their legal and ethical rights and responsibilities
- understanding whether and under what circumstances they are required to report a driver to VicRoads and if they do report, what legal protections apply to them
- understanding what happens to a person who is reported to VicRoads
- understanding more about conditional licences and whether they can recommend these.

Optometrists expressed some difficulty dealing with patients who are unwilling to accept the advice that their eyesight does not meet the required standard. They also mentioned being concerned about situations where an older patient passes the eyesight test, but appears to have other health problems that should be assessed.

Occupational therapists

On the whole, occupational therapists (OTs) were the most informed and aware group of health professionals about all issues associated with fitness to drive. The topic of fitness to drive is covered in the OT undergraduate curriculum and the availability and take up of fitness to drive professional development is high among OTs. Gaps in knowledge mostly relate to:

- clarifying the VicRoads medical review process
- information about alternatives to driving if a person needs to stop driving
- information and advice on the "grey areas" or tricky cases and where to get advice if the AFTD guidelines don't have enough detail.

c. Effective communication mechanisms, approaches and key messages

Communication mechanisms

All groups of health professionals rely on their professional associations or colleges as the primary source of relevant professional information. Each association/college that was consulted had regular communications with their members, via e-newsletters, magazines, journals, seminars, webinars and conferences. The health professional associations seemed to be very aware of the most effective types of communication for their members and were willing to assist in the dissemination of road safety information.

Providing education for health professionals at both the undergraduate and post-graduate level was mostly regarded as being important. Including at least one or two lectures about fitness to drive and forensic medicine as part of undergraduate medical studies would be helpful, as would including this topic in the undergraduate curriculum for optometry students. Similarly, including fitness to drive in the training programs for GPs, as well as for geriatricians and surgeons, would be beneficial.

It is also important that key road safety messages and advice are embedded into the clinical guidelines for managing patients with conditions that might impair their driving. This will require working with the health support organisations that develop these materials (for example, Alzheimer's Australia, Australian Diabetes Educators Association/Diabetes Australia Victoria).

Key messages for all health professionals

The most immediate communication need is to raise awareness among health professionals about their key responsibilities, the main conditions that can affect driving, and how to assess fitness to drive.

In the longer term, initiatives to encourage health professionals to take a more proactive role should be undertaken. Ideally health professionals should monitor a patient's fitness to drive, discuss this with them regularly and encourage self-regulation or cessation of driving when needed, as well as successful transition to other forms of transport.

In the future, allied health professionals such as practice nurses, diabetes educators, social workers and aged care workers, could be encouraged to become more involved in discussing fitness to drive with patients. These health professionals often have a more educative and supportive role, while GPs and specialists tend to deal more with acute medical issues. As a result they also have more time to give each patient.

Key messages for GPs

Communicating with GPs is very important as they are the front line for most patients in determining their fitness to drive. However, they are also extremely time-poor and often unable to spend the time to build their knowledge in this area and to spend a lot of time with patients in supporting them if they need to modify or cease driving.

As a result, raising awareness among GPs about fitness to drive needs to be very targeted and could involve:

- providing a short, concise summary (1-2 pages) of the key issues related to managing fitness to drive among patients
- supporting this with ongoing articles and case studies published in relevant journals, magazines and newsletters
- including case studies in the RACGP journal which focuses on professional development for GPs
- including additional information on the "for health professionals" section of the VicRoads website
- offering seminars (1-2 hours long) on the topic of the medico legal aspects of fitness to drive (which seems to be of greatest interest to GPs and other health professionals) at Medicare locals and through the RACGP
- including a lecture on fitness to drive on the program for GP registrars (arranged through the RACGP) as well as at hospital grand rounds
- including this topic or at least a lecture in the undergraduate curriculum for medical students
- targeting seminars or information to internationally trained GPs.

Key messages for other health professionals

Other health professionals would benefit from this awareness raising, but it needs to be tailored to their roles. For example, surgeons were particularly interested in information about how long to advise a patient to avoid driving after surgery. Cardiologists wanted information about what to advise people about cardiac events or heart conditions and driving. While this information is contained in the AFTD guidelines, it is probably not very easy to find for some specialists, or some may not be aware that the AFTD guidelines include this information.

Overall, health professionals are incredibly time-poor. They have large demands on their time, and need to be able to access the key information they need easily and quickly. Navigating very detailed clinical guidelines (such as the AFTD) is not practical and may not happen, resulting in subjective clinical decisions.

Communications with patients

In terms of providing written materials to patients, very few health professionals distributed or were even aware of any brochures or information about fitness to drive. Most of the GPs and other specialists expressed strong preference for one-page downloadable fact sheets on an easy to find section of the VicRoads website. These could then be printed and given to the patient. This was seen as a far more efficient way of providing material than pre-printed brochures. Suggested topics include specific health conditions and driving, transition to non-driving and how to get around without a car.

d. Implementation considerations

During consultations with health professionals, some important considerations for how communications are developed and implemented consistently arose.

Information that is included in publications or newsletters should include brief scenarios or case studies as health professionals are accustomed to this type of education. However, most health professionals suggested that any material that is developed needs to be in the voice of a peer, and that seminars or lectures should be delivered by a peer. Most other health support organisations delivered information to health professionals in a "peer to peer" manner.

Ensuring that materials are developed with relevant clinical content, are presented in a manner that is acceptable to the target audiences and using communication methods that are likely to be utilised will require input from health professional themselves.

Health checks for 75 year olds

All Australians aged 75 years and older are eligible for a Medicare funded health assessment. These are an in-depth assessment of a patient's health that is conducted in a structured way. The aim is to identify health issues and conditions that are potentially preventable or treatable, and to identify any factors that influence a person's physical, psychological and social functioning.
At present, driving is not covered in any great detail in the assessment process. However, these assessments could provide a means of encouraging a more preventative and proactive approach to how GPs interpret what a person's health status means in relation to their fitness to drive. As this is a national program, managed by the Federal Department of Health, a national approach may be needed.

Dealing with the "soft" health issues

Many health professionals expressed concern about dealing with patients who needed to stop driving. It was noted that most health professionals, especially GPs, "don't like being the sheriff", and some said they felt that they would give their patient the benefit of the doubt given the negative impact not driving would have on their overall well-being. Similar findings have been reported in other studies (Sims et al, 2012). Many health professionals also expressed concerns about a lack of alternatives to driving and helping patients deal with the process of stopping driving.

Conclusions and Recommendations

Raising awareness among health professionals will require consistent and ongoing efforts. Priority needs to be given to communicating with the health professionals who are responsible for completing medical and eyesight assessments. Fortunately a range of effective communication opportunities o mechanisms exist, primarily through the various health professional associations, peak bodies and colleges, and these need to be utilised. In addition, some key information about fitness to drive should be provided during undergraduate and post-graduate training for health professionals.

Establishing stronger relationships with the health professional associations and convening an advisory group of health professionals to provide advice on communication materials and processes will help to ensure that any materials that are developed are utilised and acceptable by the target audiences.

In the longer term, some challenges exist. Very few health professionals, with the exception of occupational therapists and some geriatricians, seemed to be proactive in discussing patients' fitness to drive with them. A more proactive and preventative health approach to discussing fitness to drive, especially with older patients is needed. Research shows that many older people will take the advice of health professionals when considering whether they are fit to continue to drive (D'Ambrosio, 2007; and Dellinger et al, 2001). Ensuring that health professionals have the knowledge and are willing to raise fitness to drive with their patients is therefore very important.

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Road User Safety Investigation for Pedestrian Priority Zones (Shared Zones) on the Gold Coast

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Abstract

In 2015, Point8 was engaged by the City of Gold Coast to develop a methodology to assess the relative safety of Pedestrian Priority Zones (PPZ). A PPZ is defined as a low speed, shared zone environment that prioritises pedestrian movements over vehicle movements and encourages pedestrian activity. The successful design of PPZs requires careful consideration of engineering elements, urban planning and landscape architecture. As a result the design of PPZ environments is complex, unique to each location and non-standardised.

Recognising the difficulty in quantifying the road safety risk of such complex environments, an assessment tool has been developed based on the Safe Systems approach. A range of safety performance outcomes related to pedestrian and cyclist safety were identified that consider both tangible engineering design aspects and less tangible environmental design considerations. The resulting tool is a PPZ safety scorecard that can be applied to existing or potential PPZ at both the concept and detailed design stages. Output scores from the tool can be used to evaluate design options for a specific site or compare the proposed design against benchmark PPZ examples to determine fitness for purpose.

The principles and general approach may have a wide range of uses to develop a similar “safety scorecard” for lower risk situations that have: limited research; unavailability of crash data to allow quantitative assessment of risk; or limited information on treatment options or design guidelines. Such a tool may be appropriate where a prescriptive design situation is not desirable (i.e. each scenario will have a unique context). Other than pedestrian priority zones, this approach may be relevant to assess the design and planning of: internal road networks within private property (e.g. mixed use developments); event management (e.g., walking or cycling event); or industrial applications (e.g. warehouses, freight depots).

Introduction

This paper outlines the development of a methodology to assess the relative safety of Pedestrian Priority Zones (PPZ). The success of PPZs requires careful consideration of engineering elements, transport and urban planning and landscape architecture. The design of PPZ environments is therefore complex, unique to each location and requires bespoke, non-standardised design. Recognising the difficulty in statistically quantifying the safety of such complex environments, an assessment tool (a “PPZ safety scorecard”) has been developed based on the Safe Systems approach.

For the purpose of developing the scorecard, PPZ are defined as a low speed, shared zone environments where priority is given to pedestrian movements over vehicle movements and the focus is on promoting pedestrian activity. Elements of urban design, place making, societal factors and commercial considerations that contribute to the design of a successful PPZ are well documented. However, limited information is available to guide the design and assessment of a PPZ to ensure road user safety. As these zones are by definition very low speed, and are not distinguishable in crash data, no research was identified that evaluates the quantitative safety of such zones.

The PPZ safety scorecard can be applied to existing or potential PPZ at both the concept and detailed design stages. While the tool has been developed to reflect the specific requirements of the City of Gold Coast (the City), the same framework can be applied to a range of similar contexts. These include situations where it is desirable to compare the assessment of risk but quantitative or subjective assessment is unfeasible due to the lack of available data and unique characteristics of each scenario. At the time of writing this PPZ safety scorecard has not been endorsed by the City.

Overview

The project brief was to develop an appropriate mechanism for assessment and comparison of risk at different project stages (e.g. existing conditions, feasibility studies, detailed design). Such a tool would assist the City in decision making, informing stakeholders when concerns are raised and ensuring assessments are impartial and consistent.

Assessment of any risk requires consideration of two fundamentals: probability and consequence. As PPZ environments typically have vehicle speeds in the order of 10km/h, in general both the probability and consequences of the potential vehicle/pedestrian conflict are significantly reduced comparative to traditional roads at higher speeds and volumes. However, while PPZ are slow speed environments, there is still an inherent risk in establishing a formalised area where vehicles and pedestrians interact. The Safe Systems approach also implies that risks other than vehicle interactions must be considered such as risks from cyclists, slips trips and falls, and accommodating mobility impaired users. In addition, to ensure the success of a PPZ in promoting a pedestrian friendly environment, the users' perception of safety must also be given a high priority.

A range of issues relevant to PPZ were researched including design features and road safety for slow speed environments, traffic rules for shared zones, and various risk assessment methodologies. Notably, no road safety research was found with regard to evaluation of risk (i.e. crash statistics) within PPZ areas. This includes comparable environments where a balanced movement of vehicles at slow speeds interact in the same physical space as pedestrians such as carparks. Because these zones are relatively low speed the incidence of serious injury or fatality in these zones is expected to be very low, and therefore is unlikely to be a topic that would attract road safety research. In the context of road safety in relation to the broader road network, the risk to road users in a PPZ (the probability of an injury occurring and the likely severity of an injury) is expected to be lower than for the majority of other urban pedestrianised environments.

As road safety literature and traffic engineering design guidelines focus on high speed environments, and the physical design of PPZ environments is inherently bespoke, there is limited guidance on design principles for these environments particularly with respect to safety. No literature could be identified that would assist designers to assess the relative safety of design options or assess a proposed location to determine suitability for a 'safe' PPZ.

From a legal perspective, Section 83 of the Queensland Road Rules states that a vehicle in a shared zone must give way to any pedestrian in the zone. With regards to implemented speed, the Queensland Road Rules do not include a legally defined maximum speed limit within a shared zone, however the Manual of Uniform Traffic Devices Part 4 recommends a speed limit of 10km/h. The City indicated anecdotal concerns with the perception of safety at particular locations where speed compliance was low and pedestrians felt at risk. During site inspections for the study, it was observed that these zones frequently see pedestrians yielding to vehicles due to safety concerns and users' unfamiliarity with the road rules in shared zones. Ensuring that all users are aware of the need for drivers to give pedestrians priority in these environments was an important objective for the project.

Considered Approaches

Based on the review of available information (including road safety and design) a range of assessment methodology options were considered to assess the relative safety of PPZ. These approaches included:

- Statistical evaluation / trend analysis. This approach is useful where significant detailed data is available that allows regression analysis or similar to establish key variables or isolate particular aspects that can be controlled. For PPZ there is limited appropriate data given the lower severity crash types and the inconsistencies in coding and reporting crashes as shared zones are not a recorded factor in crash reporting.
- Risk assessment approach / road safety auditing approach. This type of approach uses an individual's experience to subjectively assess a location. For PPZ, this type of approach limits those who can consider PPZ safety and results cannot be compared particularly given audits are done in isolation and by different people.
- Prescriptive design standard approach. This approach is suitable for situations where the same standards can be accommodated in the majority of sites. PPZ vary considerably and a 'one-size-fits-all' design solution cannot be applied. If prescriptive design standards were adopted, it is likely that relaxations would be frequently required to accommodate innovation and bespoke design options.

Framework

The assessment tool ("PPZ safety scorecard") developed combines commonly accepted road safety auditing principles and a planning scheme approach to identify desirable outcomes. The adopted road safety principles (referred to as safety traits herein) are: Warn, Inform Guide, Control and Forgive. A 'Context' safety trait was also added which underpins all the other traits by encouraging PPZ to be located in appropriate locations to manage the risk exposure of PPZ users. That is, high pedestrian numbers and low vehicle numbers reduce the likelihood of an incidence and further reinforce all other design aspects of a PPZ.

The PPZ safety scorecard adopts a familiar 'planning scheme' style where performance outcomes are identified and then corresponding acceptable solutions are provided for assessment. Each safety trait has functional characteristics and related performance outcomes which identify the strategic aims for each road user type (see Figure 1). Based on the functional characteristics and related performance outcomes, specific elements are then detailed with the absence or presence of features that contribute to safety performance categorised as desirable, acceptable and undesirable (see Figure 2). This criteria based assessment limits the subjectivity that an assessor can apply. The criteria for each element have been carefully selected to limit the need for detailed data collection while avoiding subjective assessment by the user.

The scorecard uses a weighted scoring system based around a zero average with positive and negative scoring to reflect the relative importance of elements and benefits/disbenefits to the resultant road safety outcome. The scores are tallied and each assessed site has a resultant 'safety score' that can be used to compare to other sites or other design scenarios for the same site. Weightings were refined by calibrating the scorecard to a list of existing sites that were ranked subjectively from high to low. As the scoring is based around a zero average, scores below zero highlight that further consideration should be given to the identification and improvement of unsafe elements. The scorecard allows designers to identify features that can be improved to increase safety but how these improvements are achieved is non-prescriptive.

Summary

Typical approaches for considering risk of a design of any road environment include: quantitative assessment, experienced-based qualitative assessment or compliance with prescriptive standards. In the case of a PPZ, a subjective approach was undesirable, prescriptive standards do not suit the bespoke environmental design required and statistical analysis cannot be undertaken due to lack of data. The scorecard framework is based on the Safe Systems approach and considers a range of factors that contribute to safety outcomes while acknowledging the fundamental contributors to risk are speed and exposure. This approach allows a balanced combination of design requirements and subjective assessment while providing a quantifiable comparison between different scenarios for decision making purposes.

This scorecard framework may be applied to similar situations that require a quantifiable score for comparison purposes. Such environments have risks which are not easily assessed quantitatively

and prescriptive standards are not appropriate.

SAFETY TRAIT	FUNCTIONAL CHARACTERISTICS	PERFORMANCE OUTCOMES
Context	Establish in an appropriate environment	• Vehicle volumes are low in comparison to pedestrian volumes. • Existing speeds are at a reasonable level for further reduction within the PPZ environment • Placement with the light rail corridor is avoided
Warn	Effective warnings and entry treatments.	• Pedestrians and cyclists are warned of the presence of a PPZ and are made aware of the presence of vehicles. • Vehicle users are warned of the presence of a PPZ and that pedestrian and cyclist movements should be anticipated.
Inform	Regulatory signage, environmental signals and clear design.	• Pedestrians are informed that they have priority, and should anticipate the presence of vehicles operating at low speeds. • Cyclists are informed that they are in a PPZ, the road is shared with vehicles at low speed, and that pedestrians have priority. • Motorists are informed that they are in a PPZ with an enforced speed limit, pedestrians have priority, and they must share road space with cyclists. • The PPZ environment is free of distractions that introduce significant safety concerns. Use of regulatory control devices (signs, pavement markings) is limited within the PPZ to reduce necessary information that is to be processed by users.
Guide	Directional signage and alternative route information.	• Pedestrians are given clear direction within the PPZ. • Cyclists are informed of where they are permitted to ride a bicycle within the PPZ and are offered an alternative route around the PPZ. • Direction of travel through the PPZ is established for vehicle users and alternative route options are given for travel around the PPZ.
	Unimpeded visibility	• Users are aware of and have visibility to other PPZ users at all times.
Control	Minimised length	• Vehicle speeds remain at an appropriate speed within the PPZ. • The PPZ is sufficiently long to allow for expected pedestrian demands but not excessively long such that there are sections without pedestrian movements.
	Speed reduction and compliance.	• There is raised awareness of approaching PPZ and reduction of approach speeds prior to the PPZ • Pedestrians are given time to assess potential conflicts and delay crossings or evade if necessary, but vehicle speeds are low to provide pedestrian confidence that drivers will have sufficient time to stop. • Cyclists understand that the PPZ is a low speed environment and adjust their speed accordingly. • Vehicle users have adequate time to assess and avoid potential conflict scenarios and speeds are sufficiently slow to achieve a reduction in risk of injury to other PPZ users in the event of conflict.
	Optimised cross section width	• All anticipated users are afforded adequate space for desirable movements. • Vehicle users have adequate manoeuvring space to avoid conflicts. • Undesirable movements (e.g.. u-turns) are prevented by geometric design. • Turning paths are unimpeded and the PPZ is easy to navigate.
	Limited movements and conflict points	• Movement across PPZ is encouraged due to perceived short crossing lengths. • Vehicle travel speeds are lowered due to perceived narrow travel path widths. • Vehicle movements are perceived to be constrained within defined turning paths.
	Appropriate vertical geometry	• Pedestrians and cyclists are not physically impeded by steep grades. • Vehicle speeds are not increased by steep grades.
Forgive	Unimpeded movement for non-vehicle users	• Corridor movements and PPZ activity can occur without conflicting with each other. • There is adequate provision for unimpeded movement of impaired persons within the PPZ.
	Appropriate surfaces, drainage and lighting	• Reduction of pedestrian incidents that occur through slips, trips and falls. • Luminance contrast of pedestrian surfaces and slip resistance provided between adjacent surfaces. • Reduction of cyclist and motorcyclists incidents that occur through lack of pavement friction. • Lighting fixtures provide adequate visibility for all PPZ users and adequate illumination of all surfaces at night. • Water ponding is prevented.

Figure 1. Draft Performance Outcomes

Functional Characteristics	Elements	SAFETY CHARACTERISTICS: Desirable	Score	Acceptable	Score	Undesirable	Score	Rating
Establish in an appropriate environment	Pedestrian Volumes	Pedestrian volumes are more than 1,000 per day	5	Pedestrian volumes are 500-1000 per day	0	Pedestrian volumes are less than 500 per day	-10	
	Vehicle Volumes	Vehicle volumes are less than 1,000 veh/lane/day	5	Vehicle volumes are 1,000-2,000 veh/lane/day	0	Vehicle volumes are greater than 2,000 veh/lane/day	-10	
	Approach Speed	Existing posted speed limit is 40km/h or less	3	Existing posted speed limit is 50km/h	0	Existing posted speed limit is 60km/h or greater	-10	
	PPZ Speed	The posted speed within the PPZ is 10 km/h	5	The posted speed within the PPZ is 20 km/h	0	The posted speed within the PPZ is greater than 30 km/h	-5	
	Proximity to Light Rail Corridor	There is no light rail within the road reserve.	0	A light rail corridor is located adjacent to the PPZ and there is a noticeable physical change in environment between the PPZ and the light rail corridor.	0	A light rail corridor is located adjacent to the PPZ and there is no clear distinction between the PPZ and the light rail corridor.	-7	
	Transport Network Alternative Routes	The transport network provides multiple alternative through routes.	1	The transport network provides one alternative through route.	0	The transport network does not provide an alternative through route.	-3	
Effective warnings and entry treatments.	Differentiation of Environment	A number of physical changes are located at entry points to create an awareness of entering a low speed environment e.g. pavement thresholds, landscaping treatments, change in pavement width and signage.	3	There is only one physical change located at entry points to create an awareness of entering a low speed environment e.g. pavement thresholds with signage.	0	There are no physical changes at the entry points of the PPZ.	-5	
	Shared Zone Signage and Pavement Markings	Shared Zone signage and pavement markings are present at the start of the PPZ (i.e. Shared Zone 100m ahead warnings and threshold treatments) as well as advance warning signage and pavement markings	1	Shared Zone signage is present at start and end of the PPZ.	0	No Shared Zone signage is present	-4	
Regulatory signage, environmental signals and clear design.	Narrow Perceived Width	Perceived vehicle travel paths are narrow (2.5-2.8m lane widths) through the use of methods such as pavement marking, surface and landscaping treatments	3	Perceived vehicle travel paths are 2.8m-3.5m wide.	0	Perceived vehicle travel paths are greater than 3.5m wide.	-7	
	Delineation	Landscaping/environmental treatments are implemented and provide obvious visual clues for identification and delineation of user corridors.	3	Treatments are implemented for delineation of user corridors, but delineation is not obvious at all times.	0	No treatments are implemented for delineation of user corridors	-5	
	Pavement Surface and Kerb	Both elements are provided in the PPZ: - A differential pavement surface for clear identification of a different road environment - Flush footpaths and carriageway (no kerb profile) to help reinforce the message of changed priorities.	5	One of these elements is provided in the PPZ: - A differential pavement surface for clear identification of a different road environment - Flush footpaths and carriageway (no kerb profile) to help reinforce the message of changed priorities.	0	The shared space can be perceived as a regular road environment, with standard asphalt surfacing and kerb profile highlighting a verge area.	-5	
	Distractions	There are few driver distractions within the PPZ and the potential for distraction is considered very low risk.	2	Driver distractions are present within the PPZ, but infrequent, and the potential for distraction is considered low risk	0	Frequent driver distractions exist within the PPZ and/or the potential for distraction is considered to be high risk.	-3	
	Visual Impairment	Tactile Ground Surface Indicators are provided at all pedestrian crossing locations.	1	Tactile Ground Surface Indicators are provided at some pedestrian crossing locations.	0	No Tactile Ground Surface Indicators are provided.	-3	
Directional signage and alternative route information.	Directional Signage	Wayfinding signage is provided to identify key destinations and directions of travel for both pedestrians and vehicles	1	Minimal wayfinding signage is provided to identify key destinations and directions of travel for pedestrians and vehicles	0	No wayfinding signage is provided to identify key destinations and directions of travel for pedestrians or vehicles.	-1	
	Awareness of alternative routes	An attractive alternative route exists for all vehicle through movements within 400m of the PPZ and is identified to road users prior to entering the PPZ.	2	An alternative route is available for vehicles but is not attractive and/or is further than 400m away.	0	No alternative route exists	-1	
Unimpeded visibility	Sight distance	All road users can see all other road users at all times	2	Some areas have limited visibility	0	Limited visibility for one or more road user	-2	
Minimised length	Length	Length is less than 50m	2	Length is 50-150m	0	Length is 150m+	-5	
Speed reduction and compliance	Approach threshold treatment and geometry	Various traffic calming treatments or geometry that slows vehicle speeds is implemented prior to and at the entry to the PPZ.	4	Traffic calming treatments are only located at the entry of the PPZ.	0	No traffic calming treatments or geometry that encourages low vehicle speeds is implemented.	-4	
Optimised cross section width	Crossing Points	PPZ avoids establishing pedestrian refuge areas that reinforce vehicle priority (e.g. divided carriageway with pedestrian refuge)	1	PPZ establishes pedestrian refuge areas with minimised pedestrian crossing facilities (e.g. zebra crossing across divided carriageway)	0	PPZ has established areas that may be perceived as pedestrian refuges, reinforcing vehicle priority.	-5	
	Manoeuvring space	The PPZ has sufficient space to allow for design/service vehicle movements but restricts the ability to undertake undesirable movements such as u-turns.	1	The PPZ mostly limits undesirable movements such as u-turns	0	Sufficient space is given within the PPZ to allow for undesirable movements such as u-turns.	-3	
Limited movements and conflict points	Restriction of movements	Traffic within the PPZ is restricted to one way movement and no opportunities are given to exit the carriageway within the PPZ.	3	Traffic within the PPZ is bi-directional and no opportunities are given to exit the carriageway within the PPZ, aside from property access.	0	Traffic can travel in more than one direction within the PPZ i.e. T-junction and four-way intersections.	-3	
	Delineation of crossing locations	Pedestrian desire lines are clearly highlighted within the PPZ.	3	Pedestrian desire lines are somewhat highlighted within the PPZ	0	Pedestrian desire lines are not highlighted within the PPZ	-1	
	Cyclists	Multiple measures are implemented to reduce cyclist speeds within the PPZ i.e. signage and pavement level changes at thresholds.	1	Limited measures are implemented to reduce cyclist speeds within the PPZ.	0	No measures are implemented to reduce cyclist speeds within the PPZ.	-1	
	Parking	No parking allowed within the PPZ	1	Limited parallel parking available, away from key pedestrian crossing points.	0	Angle parking provided, and/or located adjacent to key pedestrian crossing points.	-3	
	Servicing	No servicing allowed within the PPZ.	2	Limited servicing available, away from key pedestrian crossing points.	0	Servicing provided near key pedestrian crossing points and/or along majority of PPZ	-2	
	Public Transport	Public Transport stops are located outside of the PPZ area	2	Public Transport stops are located within the PPZ area and do not constrain movement corridors.	0	Public Transport stops are located within the PPZ area and constrain movement corridors.	-3	
Appropriate vertical geometry	Grades	PPZ area is level throughout entire zone	1	Majority of the PPZ is level, however one approach or section is more than 5% up or down grade	0	All of the PPZ is located within a grade that is greater than 5%	-3	
Unimpeded movement for non-vehicle users	Persons with disability	Facilities that specifically cater for unimpeded movement of persons with disabilities are provided	1	The movement of persons with disabilities will not be impeded within the PPZ.	0	PPZ facilities are inadequate to allow for all possible movements of persons with disabilities.	-4	
	Physical space	There is a clear segregation between PPZ activities (see Report for definition) and vehicle movements, and sufficient space is available for emergency manoeuvring i.e. seating and store frontages have sufficient clearance to through traffic	2	PPZ activities (see Report for Definition) can occur without conflicting with vehicle movements.	0	Reasonably anticipated PPZ activities (see Report for definition) will conflict with vehicle movements.	-3	
Appropriate surfaces, drainage and lighting	Pavement type	All surfaces and elements are slip resistant and cycle-friendly.	1	Some elements of the surfaces are prone to slip incidents and/or some elements are unfriendly to cyclists	0	Pavement surfaces are prone to slip incidents	-1	
	Lighting	Adequate illumination of PPZ	1	Lighting provided does not give adequate illumination	0	No lighting present	-1	
	Drainage	Drainage is adequate and localised ponding is avoided.	1	Localised ponding occurs after heavy rainfall.	0	Extensive ponding occurs and/or accessibility is restricted after heavy rainfall.	-1	

Figure 2. Draft PPZ Safety Scorecard

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Impact abrasion resistance quantification of protective motorcycle gloves

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Abstract

The hands are often the first contact point with the road surface in a motorcycle crash. Wearing well designed protective gloves has been proven to significantly reduce the occurrence and severity of injuries to the hand. The European Standard for motorcycle protective gloves requires testing of component materials separately and does not consider the impact of abrasive surfaces on seems.

This work aimed to develop a new method of testing of fully constructed gloves as worn by a rider in impact abrasion situations. It used previously published fall mechanics to understand the areas that may undergo impact abrasion. It defines the important zones for abrasion resistance and details ideal impact/measurement geometry for measurement on a Cambridge type abrasion tester. It proposes a method for the impact abrasion resistance of the palm, knuckles, wrist, outer side of the little finger and the tops of fingers. This information may be used for the quantification of fully manufactured gloves for standard certification or use in a rating system.

Introduction

30% of motorcycle crashes resulted in hand injuries to the rider (Otte & Middelhauve, 1987) and numerous studies around the world have found that in a motorcycle crash, riders who do not wear any form of hand protection are at severe risk of injury. Data analysed from 900 motorcycle crashes in the USA found that in all cases of hand injuries, 74% of them occurred in crashes where the rider was not wearing any form of hand protection (Hurt, Ouellet, & Thom, 1981). A more recent study analysing 226 patients admitted to a hospital in Turkey over the course of a year found very similar results for hand injury statistics (Erdogan et al., 2013). Of riders wearing gloves, 44.7% suffered soft tissue abrasion injuries, while 80% of riders without gloves suffered soft tissue abrasion injuries.

These studies highlight the need for riders to wear hand protection while riding, however in an Australian study of 212 motorcyclist involved in road crashes it was found that 25.7% of gloves designed for motorcycle use had suffered material failure during the crash (de Rome, Ivers, Fitzharris, Du, et al., 2011; de Rome, Ivers, Fitzharris, Haworth, et al., 2011). The current European Standard EN13594:2002 (Standardisation, 2002b) does not evaluate the abrasion resistance of the manufactured glove but does address the abrasion resistance of materials used in the gloves individually. A new revision of the standard (currently in publication awaiting approval) has reduced this individual test requirement and will only assess the abrasion resistance of the palm alone.

Motorcycle gloves may be designed with a specific purpose in mind, such as maximum abrasion resistance or maximum impact resistance however this design may come at the cost of suitability for use in day to day motorcycling. A thick, heavy glove will likely provide a high resistance to abrasion, however would also cause significant discomfort during use on a hot day, and is especially unsuited to the high temperature regions of Australia. When setting the standardised levels of protection, a range of potential failure modes need to be considered and ranked, whilst ensuring the levels are set to an achievable goal whilst maintaining thickness and comfort levels.

A test is required that can appraise the abrasion resistance of a fully manufactured glove as it is intended to be worn. This work outlines the design of Cambridge style impact abrasion test for a manufactured glove that will enable in use style appraisal of a gloves resistance to abrasion.

Methodology

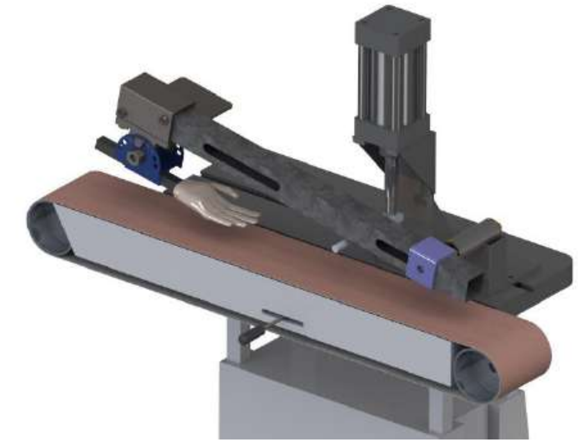
Very limited data has been published on the subject of damage to gloves. A combination of anecdotal information combined with image analysis of damaged glove images posted online after a crash was used to define the test zones of the test rig. Further research is required to improve the quality of this data.

The belt abrasion tester used for this study was based on the Cambridge impact abrasion tester as detailed in the European Standard EN 13595 (Standardisation, 2002a) and the works of R. Woods (Woods, 1996a, 1996b). It was made from a Woodmaster S-80 belt linisher (Hafco, Australia). The belt drive motor had been modified to a 1kW 3 phase motor with a FVR K7S frequency inverter (Fuji Electric, Japan) to enable belt surface speed control of up to 16m/s. The belt was an Vitex KK511X 80grit belt (VSM Abrasives, Germany). The lifting mechanism, on fabric failure, was achieved by a 100mm air actuated ram and the start/drop mechanism utilised a wedged slider acting directly on the abrasion arm. The drop height was interchangable and could be set at any height between 10-500mm. The abrasion arm was fitted so that it could run in the normal mode with a 40mm diameter abrasion surface as well as with the hand so that calibration of the belt using the standard outlined in EN13595-2 could be achieved.

The stop mechanism for the standard test was achieved using a copper break wire as detailed in the standard. The stop mechanism for the hand is still under development and has been detailed further below. The cast hand was developed using Chromax alginate impression material (Barnes, Australia) and F-170 fast set polyeurethane (Barnes, Australia). The 3D printed hand was made from acrylonitrile butadiene styrene polymer (ABS) on a Replicator 2X digital printer (MakerBot Industries, USA).

Results and discussion

The standardized abrasion rig proposed involves an abrasive belt moving at a variable speed, and an arm to drop a glove mounted to a replica hand. A concept drawing of the abrasion tester shows the three test geometries for the abrasion test (Figure 1a-c). The three different proposed positions are: outstretched fingers abrading half of the top of the finger, outstretched palm of the hand and the bottom edge of the curled fist. These test positions have been chosen to simulate abrasion and impact to the area's most commonly exposed in a crash. The outstretched hand allows for the knuckles and, with a slight angle change of the hand, the tops of the finger part of the glove to be evaluated. Knuckle damage often occurs during sliding as hands move around unrestrained. The outstretched palm will measure the palm and lower finger part of the glove that would be damaged by someone putting their hands out to arrest their fall. The bottom edge of the curled fist simulates the side of the hand impacting with the road whilst still holding the hand grip of the handle bars.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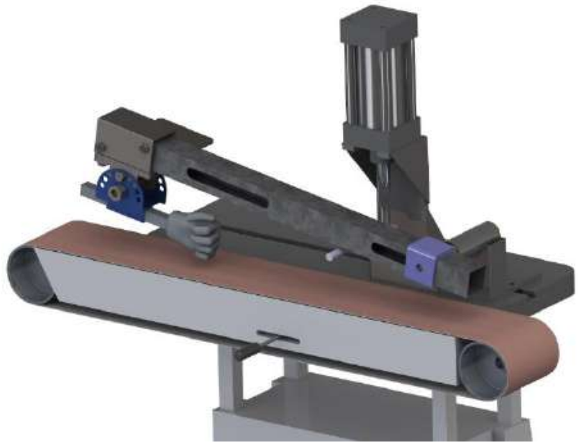
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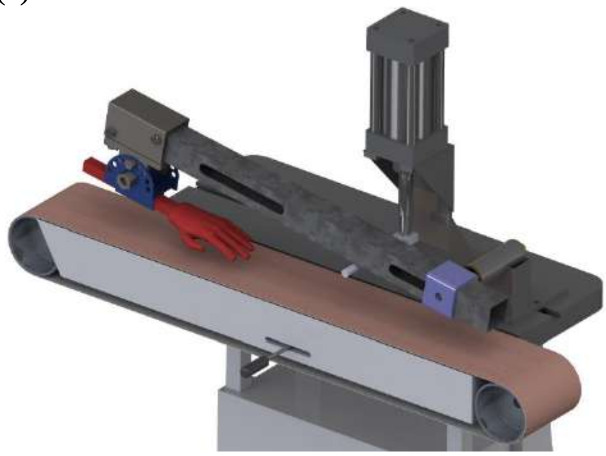
(c)

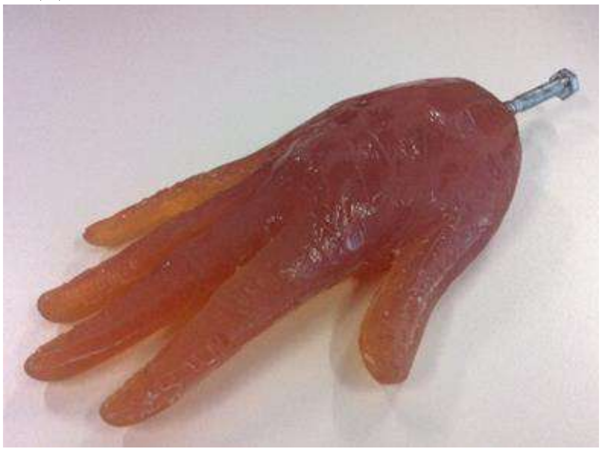
(d)

Figure 1. Concept abrasion tester with hand in the position (a) with outstretched fingers and palm up, (b) the bottom edge of curled fist, (c) outstretched palm of the hand and (d) cast polyurethane hand.

A prototype hand replica has been constructed prior to initial testing (Figure 1d). This hand was developed using a dental alginate cast of a size large hand. A polyurethane hand with a shore hardness of 40A was then made inside the alginate preform. A size large hand was selected as this was a common glove size easily obtainable from motorcycle clothing stores. The 40A hardness of polyurethane was chosen as it behaves in a similar manner to a human hand in terms of finger bending stiffness although the indent deflection is much lower with this one hardness model. Further work is required to determine the best indent hardness of the hand.

Initial fit trials with this hand showed problems with the placement of the glove over the thumb and lumps in the palm area that would cause preferential abrasion. To overcome these problems a standard hand has been designed using computer aided design (CAD) based on the dimensions of a size large hand. This hand was designed in a way that the palm of the hand was perfectly flat to enable evaluation of all parts of the palm at one time. It has been produced using a 3D printer out of ABS polymer for initial evaluation. The printed hand is being used for developing the end of test triggering mechanism. Further work will be conducted to ensure that the correct levels of flexure are achieved in the hand model and to investigate articulation of the thumb for ease in putting on gloves.

The initial two hands constructed have been used for initial fit testing, end of test triggering development and as a reference in the development of a mounting system. The final hand model will either be cast from the polyurethane using the ABS hand as the pattern or it will be 3D printed using a variable shore hardness 2 part liquid printer.

The test has been designed to abrade until failure of the protective layer. The wire end of test mechanism utilised by the Cambridge test would be too hard to adopt in a glove so a new stop system needed to be developed. Failure of the external layer will be determined by rupture of an air filled internal nitrile glove. The nitrile glove will be pressurised after the test glove has been fitted prior to testing and sudden loss of air pressure due to rupture will signal the end of the test. The glove would then be raised from the test bed to enable accurate location of the failure point and mechanism. This trigger mechanism is currently under development using the 3D printed hand.

Initial evaluation of this test system has proven positive and should enable the repeatable impact abrasion quantification of already constructed gloves. The evaluation of a fully manufactured glove is important for quality control measurement, standard certification and for a consumer evaluation program (such as a star rating system). The data obtained from this new test procedure should satisfy the requirements of all these end uses. The test should provide more information than the current European standard test as it evaluates impact abrasion effects on both the glove materials and the seams holding the glove together. Currently the test is not operational with wiring of the stop mechanism required before accuracy evaluation can commence. The mass applied to the hand at the different test configurations will need to be evaluated and optimised so that it provides abrasion times similar to those of the calibration standard.

Conclusions

A method for evaluating impact abrasion resistance of a fully manufactured glove has been proposed. The hand model, position of test specimen and test stop mechanism development have been detailed and are close to providing a prototype test device that can be used for test accuracy evaluation. The information obtained from this new test should be suitable for the quantification of fully manufactured gloves for standard certification or use in a rating system.

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The long drive home: control beliefs and commuting intentions of mine workers

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Abstract

Purpose: It is relatively common for many mine workers in Australia to drive an average of 250 kilometers to and from work following long shifts and shift blocks. Despite the long distances travelled following long shifts of 12- to 14-hours, there is evidence to suggest that these workers are not engaging in a break following their shift prior to driving home. This naturally raises issues of fatigue and sleepiness when driving. There is limited research in respect to commuting behaviours of mine workers and little is known about the factors that influence these workers to leave site immediately following their shift. Using the theory of planned behaviour, this paper examines individual control beliefs that encourage or prevent workers from leaving the site immediately following their shift block.
Method: Data was collected using a cross-sectional survey. The survey instrument was developed following a series of in-depth interviews with workers from a Queensland coal mine (n=37). The quantitative written survey sample (n=461) was drawn from the same coal mine and consisted of workers from all levels of the organisation.
Results: The results examine workers intentions to leave the work site and drive home immediately following a shift block. The results show differences in control beliefs between workers finishing night shifts compared with those finishing day shifts.
Implications: An understanding of these control beliefs may potentially inform more targeted intervention strategies in the attempt to encourage a safer approach to driving home following shift blocks.

Introduction

Between 2000 and 2014, employment in the mining industry has grown by 42% and now the industry employs approximately 269,000 people across Australia (Office of the Chief Economist, 2014). Despite the tough economic conditions faced by the industry and a general downturn in the amount of work available, workers continue to express interest toward working in the resource industry. Many mine workers in Australia live significant distances from work due to the remote location of many mine sites. As a result of these work locations, mine workers are required to commute significant distances to and from their work site following long shifts and shift blocks. Previous research describes mine workers driving an average of 250 kilometres home (Di Milia & Bowden, 2007). Within the industry this commuting practice is often referred to as long-distance commuting (LDC) or drive-in/drive-out (DIDO) work.

DIDO workers face significant risks associated with *the long drive home*. These risks include factors such as fatigue-related issues, time of day spent travelling, encountering animals on the road and driving in remote areas. In a 2009-10 report regarding work-related fatalities in Australia, the highest commuter fatality rate was recorded by the mining industry, at a rate of 2.3 commuter deaths per 100,000 workers (Safe Work Australia, 2012). Furthermore, examination of traffic crashes involving work-related driving demonstrates that crashes occurring while commuting typically resulted in more severe injuries compared to crashes occurring while working (Boufous & Williamson, 2006). Despite these risks, literature investigating the commute of mine workers has typically concentrated on the plight of the fly-in/fly-out (FIFO) worker, ignoring the issues faced by workers who are required to drive. Furthermore, due to the limited research workplace interventions tend to be inconsistent and ad hoc across organisations highlighting a need for targeted research-based guidelines and interventions.

In addition to the significant distances travelled, there is also an expectation for these workers to engage in a demanding work roster during their time on site. Mining rosters consist of a set number of consecutive work days or nights, with the worker staying in site-based accommodation during the work period. This consecutive work period is known as a shift block. The length of a shift block varies, however time on site usually ranges between 4- and 28-days. During the shift block, workers regularly engage in 12- to 14- hour shifts, sometimes working irregular hours (Di Milia & Bowden, 2007). Shift work, as well as irregular and extended hours are known risks for commuting (e.g., Scott et al., 2007). Following the end of the shift block, the worker is afforded a set number of rostered days off (between 3- and 14-days). This arrangement is known as a 'lifestyle roster' (Misan & Rudnik, 2015). At the end of the shift block, DIDO workers are expected to drive home for their rostered days off, providing it is in accordance with organisational fatigue management policies. Alternatively, the worker is provided with site-based accommodation. This practice incorporates journey and fatigue management policies, which prescribe that workers engage in a workday that is no longer than 14-hours. This workday time limitation must include the time required to commute home. However, these policies are not enforceable.

Anecdotal evidence from industry experts describe that a key problem is the propensity for workers to leave site and drive home immediately following the shift on the last day of their rostered shift block. However, it is understood that to date no research has explored the factors that motivate these workers to leave site immediately. Industry experts describe that the behaviour of leaving site straight after a shift block is more prominent when workers finish a block of night shifts. It is proposed that the variation in this behaviour is due to the time of day the driving occurs. For example, following a night shift, workers drive home during daylight hours and are more likely to perceive the driving behaviour safe. Comparatively, if workers were to leave immediately following a day shift block, then the ensuing journey would occur at night. Accordingly, it is proposed that workers finishing day shifts are less inclined to leave site immediately following the shift block. Workers have the opportunity to stay in site accommodation and rest prior to the journey home. However, regardless of the time of day the journey occurs, these workers are driving significant distances to travel home following consecutive workdays and long shifts.

Despite the strenuous work and commuting arrangements, there are many factors that contribute to continued worker engagement in the LDC lifestyle. These factors include, the perception of a comfortable lifestyle as a result of an attractive salary and flexible working arrangements (e.g., 'lifestyle roster') (Houghton, 1993; Misan & Rudnik, 2015). However, little is known about those factors which motivate workers to engage (or otherwise) in a journey immediately following a shift. This paper reports on a small component of a larger program of research, which uses the TPB to investigate influences on worker behavioural intentions to leave site immediately following a day or night shift block to commence the journey home. The key aim of this paper is to examine the beliefs underpinning the perceived control workers have in respect to leaving site immediately. These beliefs are examined by comparing those who exhibit a high intention to leave site immediately with those who exhibit a low intention. Specifically, this study focuses on those factors that encourage (facilitate) workers to leave site immediately following a shift block and those factors that prevent this behaviour (barriers).

Theoretical perspective

The Theory of Planned Behaviour (TPB) is a widely used decision making model that posits behaviour is determined by individual behavioural intentions and perceived behavioural control (Ajzen, 1991; Armitage & Conner, 2001). According to the TPB, individual intentions are determined by individual attitudes toward the target behaviour, subjective norms and perceived behavioural control (PBC). Additionally, these antecedents are informed by underlying beliefs (Ajzen, 1991). Attitudes are associated with the evaluation of the behaviour – whether the perception is positive, negative or otherwise. This attitudinal perception is based on underlying behavioural belief relating to the advantages and disadvantages of performing the behaviour (Ajzen, 1991). Subjective norms refer to the perception that those who are important to the individual either encourage or discourage the performance of the behaviour. This normative construct is based on the underlying normative belief that engaging in the target behaviour is approved or disapproved by specific reference groups (Ajzen, 1991). Finally, perceived behavioural control is the perceived amount of control one has over performing the target behaviour, which is based on underlying control beliefs. Control beliefs are internal factors that may facilitate or impede engaging in the target behaviour (Ajzen, 2002b). While these underlying beliefs are typically assessed together, the lack of previous research investigating LDC decisions of mine workers provides justification for an analysis which focuses on one belief type. The focus on control beliefs in the current study guides initial contemplation of potential educational campaigns and targeted interventions, specifically in the resource sector in Queensland and Australia.

Method

Research design and procedure

Data was collected using a cross-sectional survey distributed to mine workers during scheduled safety training sessions. Participants were recruited via convenience sampling from a large Queensland mine site based in the Bowen Basin. Ethics approval was obtained from the Queensland University of Technology Human Research Ethics Committee (approval number 1400000399).

Measures

A questionnaire was developed based on the responses of a series of qualitative interviews. This questionnaire was developed in line with standardised TPB questions (Ajzen, 1991, 2002a; Fishbein, 2003). Given the proposed variation in behaviour following day and night shift blocks, two versions of the survey were created. Both versions contained the same measures. However, one version of the survey examined behavioural intentions following day shifts and one version examined behavioural intentions following night shifts. Participants were requested to respond to one version of the survey only and their responses were based on their behavioural intentions during a typical month. Allocation to each group was random. The examination of behavioural intentions was limited to the journey home *immediately* after finishing a rostered day or night shift block. The term immediately included time to pack the car, have a shower and have something to eat. This definition was provided to participants verbally, as well as on the cover sheet of the survey. Measures were adapted from previous TPB research to align with the target behaviour and context (Ajzen, 1991, 2002b; Fishbein, 2003).

Intention to commute home immediately following a day or night shift block was measured using three items (e.g., *"I intend to drive home immediately after finishing my day/night shift block"*, *"It is likely that I will drive home immediately after finishing my day/night shift block"* and *"I am willing to drive home immediately after finishing my day/night shift block"*; 1, strongly disagree to 7, strongly agree). These items were adapted from Ajzen (1991, 2002a) and Fishbein (2003). Based on an assessment of Cronbach's alpha, these items held an acceptable level of internal consistency (α=.96). Composite scores were calculated by summing the total observations for intentions and dividing by the number of items (Field, 2013). If more than one item was missing, it was determined that the case did not have sufficient information and the case was removed from further analyses.

Control beliefs were assessed based on a series of statements which were identified during qualitative interviews (*n*=37). Participants were required to respond to nine barrier items (see Table 1) and seven facilitator items (see Table 2). Using a question stem adapted from Ajzen (1991, 2002a) and Fishbein (2003), participants were asked to respond to questions associated with the likelihood that a barrier or facilitator statement would encourage or prevent the behaviour of driving home immediately following a shift block (e.g., *"How likely is it that the following factors would encourage you to drive home immediately after finishing a day shift block in a typical month"* and *"How likely is it that the following factors would prevent you from driving home immediately after finishing a day shift block in a typical month";* 1, very unlikely to 7, very likely).

Results

Participants

Of the 492 surveys distributed, 461 responses were received resulting in a response rate of 93.7%. Participants responding to the night shift survey made up 48% of respondents (*n*=222) and those responding to the day shift survey made up 52% of respondents (*n*=239). As would be expected, males make up the majority of the respondents (89%), with an average age of forty years. Mine operation occupations, such as operators, drill specialists and blast specialists represented the 69% of respondents. The sample showed an average industry experience of ten years. The average daily shift is 12-hours, which is consistent with the trend in the industry (Di Milia & Bowden, 2007). Participants reported travelling significant distances to get home (*M*=437 kms). Despite the long distances travelled, 76% of respondents admit to leaving site within two-hours of the end of their *night shift* block (*M*=184 mins, *SD*=144 mins) and 65% report leaving site within two-hours of the end of their *day shift* block (*M*=211 mins, *SD*=262 mins). The average number of rest breaks during the journey home is two, with 28% of respondents suggesting that they don't have a break at all. If a break occurs, it lasts an average of 25 minutes.

Preliminary data analysis

An independent samples t-test was conducted to compare intention to leave site immediately following a *day* (M = 5.33, SD = 1.89) and *night* (M = 4.82, SD = 1.99) shift block. There was a significant difference in the mean intention scores for workers finishing night and day shifts (t (458) = 2.81, p = .005, two-tailed). This finding suggests that that intention to leave site immediately is greater after day shifts than night shifts. However, the magnitude of the differences in the means (mean difference = .51, 95% *CI*: .15 to .87) was very small (*Cohen's d* = 0.26; r = 0.13).

Control belief-based analyses

A series of MANOVA's were performed to investigate if there were any significant differences between control beliefs and workers with low and high intentions to drive home immediately following a day and night shift block. Given the proposed variation in intention between day and night shifts, separate MANOVA's were performed. Research examining salient beliefs has adopted this analysis technique in order to assess the difference in salient beliefs (including control beliefs) between individuals who engage in the behaviour and those who do not. This analysis technique has been used to examine differences in behavioural intentions associated with concealed texting while driving (Gauld, Lewis, & White, 2014), breast self-examination (Mason & White, 2008) and young driver speeding behaviour (Horvath, Lewis, & Watson, 2012).

The dependent variables represent control beliefs (facilitators and barriers to leaving site immediately following a shift block). As highlighted, industry experts describe a difference between the behaviour of workers finishing *day shifts* and those finishing *night shifts*. Accordingly, in order to appropriately assess this difference, the independent variable, *intention*, was transformed into a dichotomous variable by splitting the variable at the median on both the night shift (*M*=5.67) and day shift (*M*=6.00) responses. For example, those participants with total response on the intention scale lower than the median were categorised as *'low intenders'* and those falling above the median were categorised as *'high intenders'*. This procedure created four categories. These categories include, low intender following night shifts (*M*=3.14, *SD*=1.56), high intender following night shifts (*M*=6.41, *SD*=.49), low intender following day shifts (*M*=3.46, *SD*=1.62) and high intender following day shifts (*M*=6.62, *SD*=.46). Separate MANOVAs were performed for each shift type to further investigate the differences between the control beliefs of high and low intenders for both shift types. Preliminary assumption testing was conducted to check for normality, linearity, univariate and multivariate outliers, homogeneity of variance-covariance matrices and multicollinearity. No serious violations were noted.

Barriers

Analysis of factors that impede travel immediately following shift demonstrated that there was no significant difference between high and low intention following *day shifts*, F (9, 218) = 1.30, p = .24; Wilks' Lambda = .95; partial η^2 = .05, or *night shifts*, F (9, 199) = 1.45, p = .17; Wilks' Lambda = .94; partial η^2 = .07. Univariate analyses were assessed using Bonferroni-adjusted alpha level to account for Type 1 error (p< .005) (Field, 2013). Further univariate analyses demonstrated no significant differences between each barrier statement between high and low intenders for both shift types (see: Table 1).

Table 1. Comparison of low and high intenders on barrier items split by shift block

	Low intenders Mean (SD)	High intenders Mean (SD)	*F*	Sig.	Partial Eta^2
Barriers					
Day shift	*n* = 94	*n* = 134			
1. Workplace policies	4.94 (1.53)	4.96 (1.90)	.01	.936	.000
2. Avoid driving at dawn/dusk	4.86 (1.69)	4.19 (2.01)	7.08	.008	.030
3. Avoid night driving	3.99 (1.93)	3.59 (2.14)	2.09	.150	.009
4. Feeling tired	5.76 (1.49)	5.24 (1.96)	4.64	.032	.020
5. Seeing an accident	4.17 (1.86)	3.93 (1.79)	.94	.334	.004
6. Being involved in an accident	4.63(1.98)	4.46 (2.01)	.38	.541	.002
7. Fatigue management	4.53 (1.62)	4.17 (1.95)	2.16	.143	.009
8. Get home in "one piece"	5.74 (1.38)	5.39 (1.77)	2.67	.104	.012
9. Not get home tired	4.61 (1.74)	4.14 (1.90)	3.54	.061	.015
Night shift	*n* = 101	*n* = 108			
1. Workplace policies	4.92 (1.75)	4.55 (1.80)	2.33	.128	.011
2. Avoid driving at dawn/dusk	4.25 (2.05)	3.94 (1.96)	1.20	.276	.006
3. Avoid night driving	3.66 (2.09)	3.61 (1.92)	.04	.851	.000
4. Feeling tired	5.57 (1.82)	5.14 (1.90)	2.85	.093	.014
5. Seeing an accident	4.01 (2.04)	3.51 (1.94)	3.31	.070	.016
6. Being involved in an accident	3.99 (2.10)	3.88 (2.12)	.14	.706	.001
7. Fatigue management	4.13 (2.03)	3.74 (1.85)	2.09	.150	.010
8. Get home in "one piece"	5.38 (1.93)	5.16 (1.85)	.70	.403	.003
9. Not get home tired	4.72 (1.96)	4.15 (1.81)	4.86	.029	.023

* Significant at Bonferroni-adjusted alpha level (p< .005)

Facilitators

There was a statistically significant difference between high and low intention to leave immediately following *day shifts* based on worker facilitating control beliefs, F (7, 219) = 9.27, p < .005; Wilks' Lambda = .77; partial η^2 = .23. As with the univariate analyses performed to analyse the barrier items, statistical significance was assessed using Bonferroni-adjusted alpha level (p< .005) (Field, 2013). These analyses demonstrated that low and high intenders differed significantly on all facilitating factors, except carpooling (see: Table 2).

Low and high intenders to leave immediately following *night shifts* significantly differed in relation to facilitating control beliefs, F (7, 204) = 16.78, p < .005; Wilks' Lambda = .64; partial η^2 = .37. Univariate analyses demonstrated that low and high intenders differed significantly on all facilitating factors (see: Table 2). Additionally, these effects were greater for those with high intentions to leave site immediately following a shift block compared to those with low intentions.

Table 2. Comparison of low and high intenders on facilitator items split by shift block

	Low intenders Mean (SD)	High intenders Mean (SD)	*F*	Sig.	Partial Eta^2
Facilitators					
Day shift	*n* = 94	*n* = 133			
1. Carpooling	4.69 (2.01)	5.41 (2.18)	6.46	.012	.028
2. Needing to be somewhere	5.00 (1.74)	5.80 (1.60)	12.71	.000*	.053
3. Routine	3.86 (2.00)	5.62 (1.84)	47.03	.000*	.173
4. Experienced distance driver	3.61 (1.92)	4.96 (1.80)	29.47	.000*	.116
5. Car made for country roads	2.95 (1.71)	4.56 (1.92)	42.27	.000*	.158
6. Sick of being on site	4.01 (2.03)	4.93 (2.00)	11.58	.001*	.049
7. To get the drive over with	3.72 (2.02)	4.56 (1.96)	9.71	.002*	.041
Night shift	*n* = 101	*n* = 111			
1. Carpooling	4.53 (2.32)	6.04 (1.79)	28.03	.000*	.118
2. Needing to be somewhere	4.25 (2.17)	5.60 (1.77)	24.99	.000*	.106
3. Routine	3.37 (2.15)	5.83 (1.48)	95.76	.000*	.313
4. Experienced distance driver	3.04 (1.91)	5.10 (1.89)	62.16	.000*	.228
5. Car made for country roads	2.70 (1.69)	4.33 (2.03)	40.01	.000*	.160
6. Sick of being on site	3.28 (2.12)	5.15 (1.86)	47.28	.000*	.184
7. To get the drive over with	2.99 (1.99)	4.98 (1.95)	54.07	.000*	.205

* Significant at Bonferroni-adjusted alpha level (p< .005)

Discussion

The aim of this study was to examine the factors that facilitate or prevent (barriers) workers leaving the mine site immediately following a shift block. Given the anecdotal reports of industry experts, the results provided a comparison between the behavioural intentions following a day and night shift block. While there was a statistically significant difference which demonstrated that workers held a stronger intention to leave site immediately following *day shifts*, the difference was very small. However, a greater number of workers admit to leaving site within two-hours of the end of *night shifts* than *day shifts* (11 percentage point difference).

If workers leave site immediately, the average number of kilometres/hours spent driving home (M=437 kms; M=248.99 mins) would indicate that workers spend approximately 16-hours working and driving on the last day of the shift block. However, this time does not include time to get ready for work before the shift, getting ready to leave the site or other miscellaneous factors. Therefore, it is reasonable to consider that drivers could be awake for up to 20-hours on the last day of shift. Research has demonstrated that 17-hours of wakefulness results in driving performance that is equivalent to a blood alcohol concentration of 0.05%; with each additional hour contributing a 0.004% rise (Dawson & Reid, 1997).

There were notable variations between factors which facilitate leaving site immediately following day and night shifts. These variations are discussed in detail below, but are predominately due to the type of shift (e.g., day or night). However, it is difficult to draw comparisons with previous research, as research investigating worker motivations to engage in LDC typically explores factors associated with worker motivations to work in remote locations (e.g., Haslam McKenzie, 2010; Houghton, 1993; Misan & Rudnik, 2015).

Barriers

Using a Bonferroni-adjusted alpha level there were no statistically significant differences between barriers and either intention category following a day or night shift block. However, following a *day shift block*, *avoiding driving at dawn/dusk* is approaching significance. Specifically, *low intenders* are more likely to *avoid driving at dawn/dusk* when compared to *high intenders*. This result is consistent with workers finishing their final *day shift* around dusk when there is a higher risk of animals on the road. However, there is no relationship between *intentions* and *avoiding driving at dawn/dusk* following night shifts. The lack of relationship could be due to the limited opportunity for a worker to drive at either dawn or dusk given that a typical night shift concludes at 06:00hrs.

In respect to those workers finishing *night shifts*, inspection of the barrier items reveals that *not getting home tired* is also approaching statistical significance. Given the consecutive nights awake, it is likely that these workers are tired due to the change in their sleeping patterns and irregular work hours (Scott et al., 2007).

Facilitators

A Bonferroni-adjusted alpha reveals statistically significant differences on all facilitators (except carpooling) for both shift types. Based on the inspection of the mean scores of each group, high intenders were more likely to be encouraged to leave immediately after a *day shift* block when compared with low intenders due to the perception that they are an *experienced long distance driver*, due to their *routine* following a shift and *owning a car built for country roads*. Finally, the mean scores for *needing to be somewhere* facilitated leaving the site immediately following a day shift block for both low and high intenders.

When considering the mean scores of low and high intenders following *night shifts,* high intenders were more likely to be encouraged to leave immediately after a shift block when compared with low intenders due to holding the perception that they are an *experienced long distance driver*, due to their *routine* following *night shifts*, *owning a car built for country roads*, because they are *sick of being on site* and to *get the drive over with*. Furthermore, high intenders appear more likely to want to leave immediately following night shifts because they are *sick of being on site*. Finally, *needing to be somewhere* and *carpooling* facilitated leaving the site immediately after a night shift for both low and high intenders.

Regardless of shift type, *routine* following a shift block was more likely to facilitate a journey home immediately for high intenders when compared to low intenders. Further inspection of the factors facilitating intentions following *day shifts* reveals that *routine* explains 17.3% of the variance in *intention* to leave site immediately following a shift block. This finding demonstrates that workers develop an after work routine that they implement at the conclusion of *day shifts*. Furthermore, *routine* following *night shifts* explains 31.3% of variance in *intention,* a 14 percentage point increase. This finding demonstrates that the influence *routine* following a *night shift* has on *intention* to leave immediately is much more pronounced. Research describes mining camp life as regimented, suggesting that workers have set routines and processes for all tasks (Misan & Rudnik, 2015). It could be suggested that the *routine* surrounding the preparation for the journey home is associated with the regimented nature of life on-site. Alternatively, the routinised behaviour may have been ingrained from the start of the worker's DIDO career. Changing routinised behaviour is difficult. In order to encourage a safe journey home, the *routine* of leaving immediately following a shift needs to be challenged. However, the difference between behavioural *intentions* following *day* and *night shifts* in respect to *routine* demonstrates that a standard approach to policy, regardless of shift type, would be misguided.

Another facilitator which influences intentions to leave site immediately, particularly following a number of consecutive *night shifts*, is the premise that workers are *sick of being on* site. It was identified in the broader program of research that workers prefer to leave site as soon as possible to get back to 'civilisation'. This need to get back to civilisation is more identifiable following night shifts due to the time of day work is performed and the isolating nature of that shift type.

As mentioned, the findings of this study demonstrate that these workers drive an average of 437 kilometres home following a long shift. The results show that the urge *to get the drive over with* explains 20.5% of variance in intentions to leave immediately following *night shifts*. This finding is notably higher when compared to the amount of variance this facilitator explains following *day shifts*. Following consecutive *night shifts*, workers are exhausted and want to get home to start their rostered time off. However, the *long drive home* is the final 'hurdle' to overcome before they are able to relax.

Finally, the results demonstrate that high intenders are *"somewhat likely"* to be influenced by the perception that they are an *experienced long distance driver* across both day shift and night shift. When considering the mean scores, there is a propensity for high intenders to leave site immediately following a shift block, regardless of the shift type. However, the amount of variance explained by workers perceiving that they are an *experienced long distance driver* is higher following *night shifts* than *day shifts* (11 percentage point increase). Research considering rural and remote driving describes an optimism bias which suggests that road users who frequently drive in rural and remote areas, or those who grew up driving on country roads, perceive that they are a better than other drivers in those areas (Sticher & Sheehan, 2006). Furthermore, there is a perception that if a crash were to occur it would be the fault of the other driver or some external factor (Sticher, 2005). Rural and remote road users perceive that the factors which determine crash risk include the age of the driver, type of vehicle driven and the familiarity with the road (Sticher & Sheehan, 2006). The findings of this study are consistent with optimism bias, which appears to be stronger following night shift blocks. Optimism bias was identified throughout the in-depth interviews in the broader program of research.

Strengths and limitations

Using the TPB, with a focus on control beliefs, this study was able to provide an initial understanding of the facilitators and barriers of leaving site immediately following a shift block. A key strength of this study is the use of a well-validated theoretical framework. Furthermore, while industry experts have previously proposed that shift type influences commuting behaviour immediately following shifts, this study is the first to provide evidence of this influence using empirical methods.

The sample was relatively large (day n = 239, night n = 222) and was drawn from a large mine site in the Bowen Basin. This mine site is a DIDO mine with a limited number of workers opting to FIFO. There are limitations in the generalisability of these results given the focus of this study on one DIDO site. However, the sample is generally representative of the mining population as a large proportion of the site was sampled (93.7%). Furthermore, the sample covered all levels of the organisation; from operational-level workers through to management. While the sample was only drawn from one mine site, the average number of years in the industry for participants indicates a high-level of experience in the industry. However, future research should consider similar research across multiple sites.

The participants were asked to self-report about their journey following shift blocks. The self-reporting requirement and the completion of the surveys during work-hours may have led participants to respond in line with company commuting policy due to concerns that the information they provide would not be treated as confidential. However, the results demonstrate that the majority of respondents admitted to leaving site within two-hours of the shift block. This result confirms that on average these workers do not engage in a rest break prior to commuting home. With an average commute time above 4-hours, leaving site without a break means that workers would exceed the 14-hour maximum day, which is in contrast to organisational policy. Given the disclosure about the typical rest break following shifts, it is suggested that there is no issue with social desirability bias or participants being concerned about confidentiality.

Conclusion

The current study is understood to be the first to provide insight into the factors that facilitate and act as a barrier to mine workers leaving immediately following day and night shift blocks and driving home. While initial inspection of behavioural intention reveals a stronger propensity to leave immediately following *day shifts*, this cursory glance fails to consider the facilitators that are more pronounced following a *night shift*. These facilitating factors include *routine*, being *sick of being on site*, *to get the drive over with*, and because workers perceive that they are and *experienced driver*. While industry experts describe the key facilitator for leaving immediately following a night shift as the time of day the journey occurs, these results highlight the complexity of these facilitating factors. The complexity indicates that potential educational campaigns and targeted interventions need to consider the variation in intention and behaviour of worker commuting between shift types.

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Heavy Vehicle Safety: the role of roadworthiness

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Abstract

The Heavy Vehicle National Law (HVNL) prescribes standards that must be met by a heavy vehicle before it can be used on the road. The HVNL also makes it an offence to use on a road, or permit to be used, a heavy vehicle that is unsafe. Despite this, there have been a number of recent serious road crashes in which an unsafe or unroadworthy heavy vehicle was involved. This paper will describe the findings of work undertaken by the National Transport Commission (NTC) and the National Heavy Vehicle Regulator (NHVR) to identify potential improvements to the way in which heavy vehicle roadworthiness can be assured. These will include both regulatory and non-regulatory approaches, as well as measures that could improve the effectiveness of accreditation schemes designed to ensure good maintenance practices.

The challenges faced in obtaining relevant data to define the scope of the safety issues associated with Heavy Vehicles that have not been maintained in a safe condition, and to determine the effectiveness of proposed safety interventions will also be discussed.

Introduction

Recent data shows that a significant proportion of the fleet of heavy vehicles carry a defect — for example the majority of vehicle combinations (prime movers and any trailers) carry a defect (NTC, 2015) and, of these, 13 per cent carry a major defect. Across the whole heavy vehicle fleet, 0.5 to 10 per cent of inspected vehicles have a major defect, depending on vehicle type.

Unroadworthy heavy vehicles impose significant costs on Australian society. They compromise the safety of drivers and other road users and impede productivity.

In addition to the human suffering related to crashes involving heavy vehicles, the economic costs of heavy vehicle road crashes associated with vehicle defects and traffic congestion caused by breakdowns that are attributed to poor maintenance are significant.

The NTC, together with the NHVR, have been undertaking a program of work to identify ways by which the level of roadworthiness of the Australian heavy vehicle fleet can be improved, with consequent improvements to their safety and efficiency.

Discussion

Examination of the current situation identified several areas which needed to be addressed. In particular, roadworthiness procedures were not being consistently applied across Australia. Some operators were not meeting acceptable standards of roadworthiness. Fleet-related data collected by authorities on roadworthiness was variable and incompatible. Insufficient market incentives existed for heavy vehicle maintenance to be conducted to the standard required. The NHVAS maintenance module suffered from limitations in governance and process.

Measures to improve the situation can be classified into four key areas:

National standardisation & consistency

Better and nationally agreed criteria for the uniform application of roadworthiness standards and procedures and criteria for assessing heavy vehicle roadworthiness, classifying defects, conduct of standardised inspections and procedures and consistent, transparent compliance requirements.

Improved compliance

Providing the NHVR with better tools for proactive and cost-effective interventions has the potential to deliver effective and long lasting action to raise levels of compliance.

Inspection of vehicles

Providing greater consistency in the approach to vehicle inspections, including the targeting of resources to areas of greatest risk has the potential to raise standards of roadworthiness across Australia.

Strengthening the National Heavy Vehicle Accreditation Scheme (NHVAS)

The introduction of new business rules relating to auditor qualifications and oversight arrangements by NHVR have been agreed and are now being implemented by the NHVR.

Future actions

Specific measures relating to these four areas will be considered by relevant Ministers in late 2015.

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The hurdles of introducing innovative road safety infrastructure solutions – a case study on raised Safety Platforms

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Abstract

It will be very difficult to achieve a perfectly Safe System on our road network (i.e. zero fatalities or serious injuries) without the introduction of new and innovative road infrastructure treatments. There are treatments that exist overseas and have proven effectiveness; however the uptake of these solutions in Australia has been limited in many cases. This is due to a number of issues, including lack of knowledge on their use and effectiveness, lack of experience with design and implementation, and risk aversion.

This paper will discuss issues relating to the future uptake of innovative infrastructure solutions through the case study of raised Safety Platforms on approach to signalised intersections on arterial routes – a new road infrastructure treatment that VicRoads has been in the process of researching, trialling and implementing on Victorian roads. The aim of this treatment is to achieve Safe System vehicle speeds through intersections (50 km/h). Although this infrastructure is used extensively overseas (e.g. in the Netherlands), it has yet to be introduced on arterial roads in Australia. ARRB undertook a comprehensive literature review on the likely benefits of these treatments, performed trials to establish vertical accelerations and driver comfort levels in a variety of vehicle types and performed modelling to assess the effects of road slope on effectiveness. VicRoads is currently in the process of installing the raised Safety Platforms at an intersection near Geelong, Victoria, and is due for completion in July 2015.

Introduction

The Safe System approach focuses on eliminating fatal and serious injuries as a result of crashes and promotes a shared responsibility between road agencies, the driver and car manufacturers to create a safe road environment for all road users (ATC 2011). This approach emphasises the need for a 'forgiving' system, where road users do not face the risk of serious injury or death while adhering to the road rules (Elvik et al. 2004).

Australian road authorities have adopted the Safe System approach; however it is understandable that achieving zero fatal and serious injuries on the Australian road network is not a task that can be done overnight. Current road safety treatments, regardless of expense, result in some reduced serious crash outcomes, but do not achieve a completely Safe System. For example, a roundabout or signals can be installed at an intersection to improve road safety, but each only attains a crash reduction of 55% and 30% respectively in an urban setting (Austroads 2013a). There is a need to develop new innovations and to adapt existing treatments so that better crash risk reduction can be obtained.

There are also a number of highly effective treatments that already exist, but are currently not being utilised in Australia. There is still reluctance to incorporate new treatments due to a lack of knowledge, existing evidence of a treatment's effectiveness, and issues with public acceptance and legal liability. This paper will discuss how some of these issues can be negotiated through a case study on raised Safety Platforms at signalised intersections on arterial routes – a new road infrastructure treatment that VicRoads has been developing, trialling and implementing on

Victorian roads – as well as the need for an innovation framework to help agencies fast track the introduction of new treatments in future.

The structure of this paper is as follows:

- introduction
- case study (problem identification, literature review, off-road trial and current status)
- discussion of issues relating to innovation
- concluding remarks.

Note that the term 'Safety Platform' is used throughout to describe a raised platform just prior to an intersection, in accordance with VicRoads' definition.

Case Study – Problem identification

Intersections are often the source of major fatal and serious injury crashes and are often a challenge for road safety practitioners. At intersections, there are a high number of conflict points which create opportunities for vehicles to collide. When the vehicles collide, the impact forces influence the likelihood of a fatality or serious injury. The goal at intersections should be to reduce these impact forces to levels that do not result in a fatality or serious injury.

One method to achieve these lower impact forces is to reduce vehicle speeds through the intersection. Research has indicated that vehicle speeds over 50 km/h dramatically increases the chances of death and serious injury in the event of a crash between two vehicles at an intersection (Fildes et al. 2005). When vehicle speeds are kept at or below 50 km/h through intersections, the chance of death is less than 10%. For side-impact collisions, particularly at 90 degree angles, the likelihood of injury greatly increases above 50 km/h.

The aim of VicRoads' study was to install vertical displacement treatments (i.e. speed humps) in order to reduce vehicle speeds to 50 km/h through a signalised intersection in a 70 km/h speed environment. In the context of this paper, raised Safety Platforms specifically refers to a flat top speed hump.

Case Study – Literature review

In early 2014, VicRoads commissioned ARRB Group to undertake a literature review and present recommendations for ideal profile and dimensions for a vertical displacement treatment at signalised intersections. A brief summary of the literature review findings are presented in this paper; the full details of the literature review will be provided in a published report. A literature review was undertaken to explore the different uses and design profiles of three types of vertical displacement treatments, as nominated by VicRoads:

- Watts profile road humps
- flat top road humps
- raised intersections.

The review also brought attention to additional design types, such as sinusoidal profile road humps, road cushions, and raised pedestrian crossings.

The review sought to draw conclusions on how to achieve the Safe System vehicle speeds of 50 km/h through an intersection whilst considering different vehicle types (including bus services), passenger comfort, and emergency services access. Literature review searches revealed that although there is a great amount of available information on road hump performance, there is limited information on hump performance for a 50 km/h crossing speed or road hump implementation at intersections. Consequently, the review initially presented some information on design standards for local roads (i.e. lower speed environments) and road hump effectiveness at midblock locations to provide further background on overall hump performance. VicRoads provided some material for review, and input was also sought from councils as to their experiences with implementation, community acceptance and any other issues encountered.

There is also limited information on road humps and platforms with a design speed of 50 km/h. The literature review revealed that although current Austroads guidelines state that road humps and raised intersections are not suitable for locations where speed limits are posted above 60 km/h (Austroads 2008), a number of studies showed that 50 km/h vehicle speeds can be achieved whilst maintaining some level of driver comfort.

The literature review also considered:

- the impact on emergency and bus service operation
- catering for pedestrian activity at intersections
- noise pollution
- the impact on neighbouring streets/service lanes
- damage to vehicles/pavement
- difficulties that may be encountered when retrofitting to existing intersections.

In general, the flat top profile was seen as the least restrictive in terms of ease of installation and replication, benefits to different road users and lower cost.

Effectiveness of raised treatments at intersections

Raised Safety Platforms are a common instalment at both signalised and unsignalised intersections in the Netherlands (Candappa & Corben 2011). Safety Platforms are sometimes used on the approach to an intersection, rather than through the intersection itself. A number of studies around the world have shown raised intersections to be effective in achieving vehicle speed reduction and crash reduction. Table 1 provides a summary of the findings from these studies.

Table 1. Summary of the effectiveness of raised Safety Platforms at intersections

Reference	Site	Key treatment(s)	Effects on speed and crash reduction
Austroads (2011)	Mahoe Street, Hamilton, New Zealand	Raised intersection (traffic volume 3,000 vpd)	• 85th % speed: -1.1 km/h
Watkins (2000)	Cambridge, Massachusetts, USA	Raised intersection (2 sites: 8,100 and 4,400 vpd)	• 85th % speed: -5 mph (8 km/h) & -4 mph (6.4 km/h) • % drivers exceeding 25 mph (40 km/h): 57% to 17% & 39% to 14%
Reekmans et al. (2004)	The Netherlands & Australia	Raised intersections	• 20–60% crash reduction • 25–80% casualty reduction
Van der Dussen (2002)		82 intersections, 10 treated with raised plateaus	• 80% crash reduction (in comparison to 57% at roundabouts and 46% at traffic signals) • 80% injury crashes reduction

			• 60% property damage only crash reduction • Cheaper to install over roundabout/signals conversion

Source: Austroads (2013b); Harms & Turner (2013).

The UK Mixed Priority Routes Road Safety Demonstration Project (Gordon & Barrell 2008, in Austroads 2013b) assessed raised intersection tables at four locations in combination with other speed management treatments. These were primarily high volume bus routes with posted speed limits of 30 mph (48 km/h). Table 2 provides a summary of the project results, including percentage changes in mean and 85th percentile speeds, and percentage change in casualties. Note that because in some cases multiple treatments have been applied, it is therefore not possible to determine the effect of the raised intersection component.

Table 2. Summary of project results for UK Mixed Priority Routes Road Safety Demonstration Project 2008

Site	**Key treatments**	**Change in mean speed**	**Change in 85th % speed**	**Crashes**
The Parade/ Victoria Tce, Leamington Spa	Lower speed limit, road narrowing, raised junctions, cycle lanes	-5–19% (to under 20 mph (32 km/h) speed limit)	-5–17% (to between 19–23 mph (30–37 km/h))	• Average annual casualties dropped from 14 to 8.6 • 0% reduction in speeds (possibly skewed by major bus crash involving many passengers)
Cowley Rd, Oxford	Raised carriageway and junctions, additional crossings, extended kerbs	-10% (2.7 km/h)	-10% (3.4 km/h)	• 36% reduction in crash frequency • 55% reduction in cyclist crashes • 18% reduction in pedestrian crashes
Walworth Rd, Southwark	Raised crossings at junction, wider footpaths, improved signalling	N/A	N/A	• 46% reduction in slight casualties • 0% reduction in serious injuries • 42.5% overall crash reduction
St Peters St, St Albans	Raised table with crossings, gateways, carriageway shift	-8% (3.2 km/h)	-4%	• 38–50% reduction in injury crashes

Source: Austroads (2013b); Harms & Turner (2013).

It should be noted that three of the sites experienced reductions in traffic due to the treatment implementation (Harms & Turner 2013).

Fortuijn, Carton and Feddes (2005) assessed the safety effects of raised Safety Platforms at 29 intersections in the Netherlands. At a controlled intersection, the Safety Platforms were typically 120 mm high with a 6 m long plateau and 1:30 ramps. From a safety viewpoint, the authors stated that a reduction in speed to 30–35 km/h was desirable. The authors studied 40 signalised intersections and 29 priority (unsignalised) intersections for a three-year period (where data was available) before and after the installation dates of Safety Platforms. The resultant safety effects are shown in Table 3.

Table 3. Safety effects of raised Safety Platforms at signalised and priority intersections

	Signalised intersections with Safety Platform		**Priority intersections with Safety Platform**	
	# casualty crashes /intersection/year	# crashes (total) /intersection/year	# casualty crashes /intersection/year	# crashes (total) /intersection/year
Before	1.23	7.01	0.31	1.60
After	0.74	4.50	0.20	0.90
Safety effect	-39.6%	-35.8%	-35.0%	-44.0%
Chi squared test of difference	12.0	54.5	1.51	13.1
Significance level	0.05%	0.00%	22% (non-significant)	0.03%

Source: Fortuijn, Carton & Feddes (2005).

Optimal performance design

A linear inverse relationship has been previously established between the perception of comfort and vertical acceleration (Kjemtrup 1988). In other words, as vertical acceleration increases, so does discomfort for drivers and passengers. Vertical acceleration is not only dependent on the geometric design of the hump and the vehicle speed as it travels over the hump, but also vehicle characteristics such as the suspension system, tire pressure and seat softness. Callaway, Roper and Germanchev (2010) noted that comfort was also affected by pitch, roll and steering wheel feedback. Kjemtrup (1988) and Callaway et al. (2010) both identify 1.0 g as being internationally considered the appropriate maximum vertical acceleration that one should withstand, and that vertical acceleration of above 0.5 g (0.7 g recommended) should achieve effective speed reduction. Kjemtrup also notes that the driver of a bus is subjected to a higher level of vertical acceleration than their passengers. According to Kjemtrup's trials cars were able to traverse the same road hump consistently 15–20 km/h faster than buses.

ARRB was previously commissioned by the Department of Transport to assess the effectiveness of platform-style tram stops at kerbside, which allow vehicles in the left lane to traverse the tram stop platforms (Callaway, Roper & Germanchev 2010). The platform style ramps were 290 mm high with a plateau of 6 m and ramps at various grades from 1:12 to 1:55. The study measured maximum vehicle travel speeds, adverse effects while braking, and the acceptable distance for parked cars on the ramp approach and departure for a variety of different ramp grades. The vertical acceleration threshold was set at 0.5 g as the platforms were not designed to reduce vehicle speeds, but aimed at maintaining consistent traffic flow. The resultant speeds for various vehicle types and ramp grades are shown in Table 4.

Table 4. Highest recommended posted speed limit (based on a maximum vertical acceleration of 0.5 g)

Vehicle	**Highest recommended comfortable speed (km/h)**			
	1:12	**1:20**	**1:40**	**1:55**
Motorcycle	20	50	80+	80+
Passenger car	20	50	70	80+

Medium rigid truck	20	30	60	70
Low floor bus	10(2)	20	60	70+(1)
Heavy rigid truck	20	30	60	70+(1)
B-double	20	30	60	70+(1)
Overall	10	20	60	70

1 Due to the limited approach distance, the test vehicle was not able to reach a speed of 80 km/h. The highest speed reached is listed.

2 Result based on ground clearance considerations rather than occupant comfort.

Source: Callaway, Roper & Germanchev (2010).

The braking tests indicated that vehicle stopping distances increased by 1–5 m when an emergency braking manoeuvre was performed on the off-ramp to the platform; however there were no negative effects on vehicle stability (Callaway, Roper & Germanchev 2010).

Weber and Braaksma (2000) tested vehicle speeds across a variety of Watts and Seminole profiles in Canada and the USA (see Figure 1 for hump profiles). The 75 mm high Seminole profile (6.7 m long) had the closest results to the target of this project (50 km/h), with 85th percentile speeds for passenger vehicles of 44 km/h and bus mean speeds of 30 km/h. It is also worth noting that for all tests, the peak vertical acceleration was generally between 0.5 to 0.7 g.

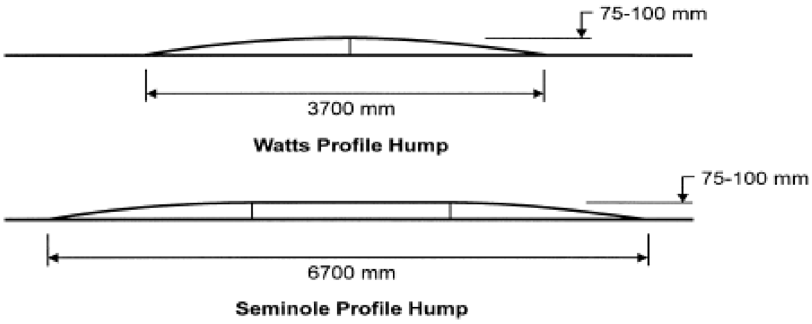


Figure 1. Watts and Seminole profile road humps

Design issues and limitations

A study in the US identified that raised Safety Platforms at intersections significantly impacted on emergency response times (Candappa & Corben 2011). Bus route timetables can also be affected by the introduction of road humps (Department of Transport 1992).

Locating raised Safety Platforms at an existing intersection can create quite a few issues, including:

- Care must be taken to ensure road humps or raised intersection ramps do not impact on vehicle turning movements. Vehicle stability could be compromised if vehicles travel up or down a ramp at an angle.
- Orientation of stop lines should preferably be at 90 degrees to the direction of travel to ensure vehicles do not travel across the ramps at an angle.
- The platform of flat top humps can act well as pedestrian crossing points; however these points must be clearly line-marked and signed to ensure there is no confusion as to when pedestrians have priority (for example, ensure that the platform is not confused for wombat crossing at a signalised intersection) and the platform must be flush with the footpath to prevent tripping hazards.
- The Safety Platform should be raised across the whole intersection if the road is undivided to prevent additional hazards to both vehicles and pedestrians in the middle of the carriageway.

- For intersections with left turn slip lanes and/or median splitter islands, hump length may be limited by the length of the islands.
- If road shoulders are present, the design should prevent vehicles bypassing the raised pavement and maintaining a higher speed.
- Drainage of the pavement should be taken into account in the design of the treatment.
- Warning signs and linemarking should alert road users to the treatment to ensure they slow down accordingly.
- Longitudinal grade of the road has not been the subject of research, and local road treatments are suggested to be placed on roads preferably with a 3% longitudinal grade (Austroads 2008).

Case Study – Off-road trial

Late in 2014, VicRoads commissioned ARRB Group to undertake on-site testing and simulation modelling of Safety Platform designs to determine expected vehicle speeds as a result of comfort levels. A brief summary of the off-road trial process is presented in this paper; the full details of the trial will be provided in a published report. The testing program focussed on three key areas:

- maximum acceptable speed to traverse each installed platform
- the vertical acceleration and pitch experience by each vehicle type at different speeds
- how this compares to the sensation of a passenger vehicle travelling over other vertical deflection devices.

In the previous literature review, it was identified that comfort is a key criteria for performance effectiveness, and road user discomfort can reduce vehicle speeds and thus improve overall safety.

VicRoads had installed two flat top Safety Platforms along Gundog Lane, Belmont, with profiles as described in Table 5 and locations as shown in Figure 2.

Table 5. Installed Safety Platform profiles

Trial	Direction	On-ramp length	On-ramp gradient	Platform length	Platform height	Off-ramp length	Off-ramp gradient
1	West	3.00 m	1:30	7.00 m	0.10 m	3.50 m	1:35
2	West	4.67 m	1:30	6.00 m	0.14 m	4.67 m	1:30

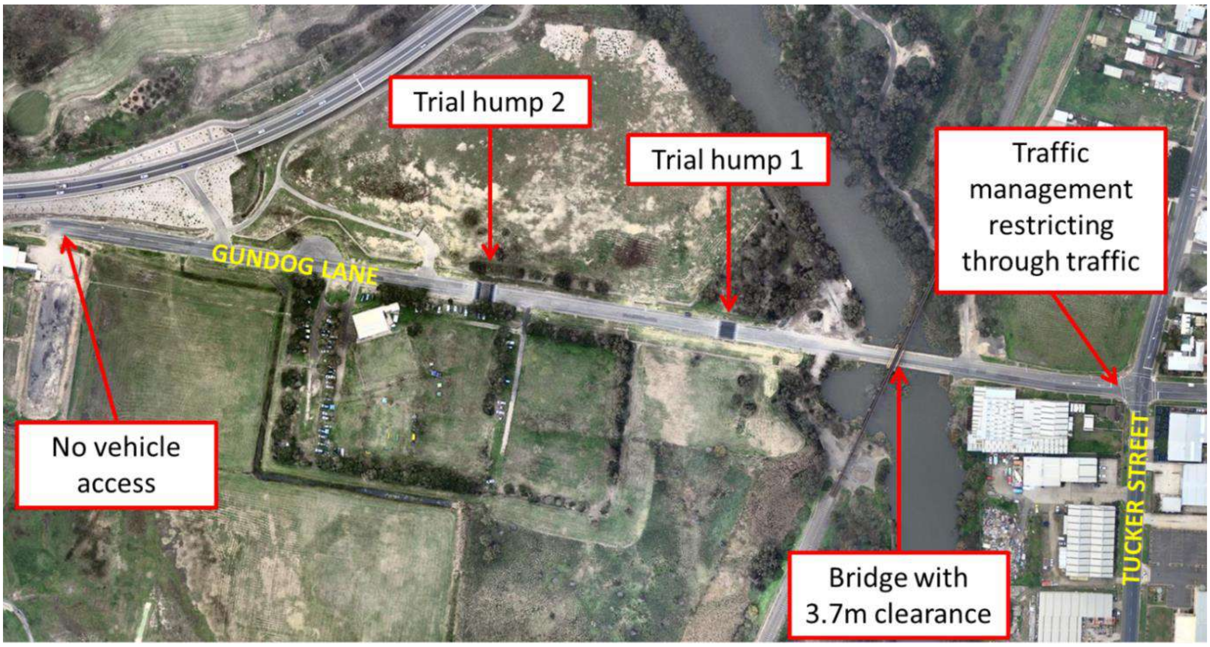


Figure 2. Trial Safety Platform locations along Gundog Lane, Belmont

A range of vehicle types were included in the study to account for differences in vehicle performance and to ensure that there was no significant negative impact on the majority of road users at potential Safety Platform sites. The vehicles selected in this study were:

- bicycle
- motorcycle (with pillion and without)
- passenger car
- heavy rigid truck
- semi-trailer
- airbag suspension bus
- spring suspension bus.

The comfort levels were measured by vertical acceleration and pitch. Ride quality data was collected for a passenger car, rigid truck, semi-trailer, airbag suspension bus and spring suspension bus. Driver/passenger feedback was collected for bicycles and motorcycles. Comparison data was also collected for typical vertical displacement treatments (i.e. conventional road humps and Safety Platforms) in the passenger car.

Based on the literature review previously undertaken, it was established that speed reduction occurred when vertical acceleration exceeded the comfort threshold (i.e. 0.5 g). Vertical accelerations exceeding 0.7 g was considered dangerous and has the potential to cause damage to a vehicle. Considering this, a range of 0.5 to 0.7 g was considered to achieve noticeable speed reduction without causing vehicle damage (see Table 6).

Table 6. Typical driver speed responses to vertical acceleration

Magnitude of vertical acceleration (g)	Typical driver response
0.1 – 0.5	No speed response
0.5 – 0.7	Some speed reduction
0.7+	Possible damage to vehicle (bottoming out)

In the on-site testing, Profile 1 (1:30 on-ramp, 7 m platform and 1:35 off ramp) was shown to be the more effective of the two profiles installed. This profile showed the smallest speed differential between vehicle types, with the following expected speed results if the treatments were to be deployed on public roads (see also Figures 3 and 4):

- passenger vehicle speeds reduced to 60 km/h
- rigid truck and semi-trailer speeds reduced to 50 km/h
- airbag and spring suspension bus speeds reduced to 40 km/h.

The red line in Figures 3 and 4 indicate the comfort threshold (0.5 g), as determined from the previous literature review. The x-axis ('target speed') indicates the speed that the driver was trying to achieve as the vehicle passed over the Safety Platforms.

Pitch data was also collected during each test, which measures the rate of change in angle of the vehicle as it traverses a Safety Platform. This can cause additional discomfort to vehicle occupants. However, the pitch angles measured during travel over all of the ramps were no more than 10 degrees per second. Anything under approximately 15 degrees per second is unlikely to be noticed as a pitching movement, especially in combination with the vertical accelerations that are occurring at the same time. Accordingly, it is the vertical accelerations which are considered more important when measuring comfort during travel over these ramps.

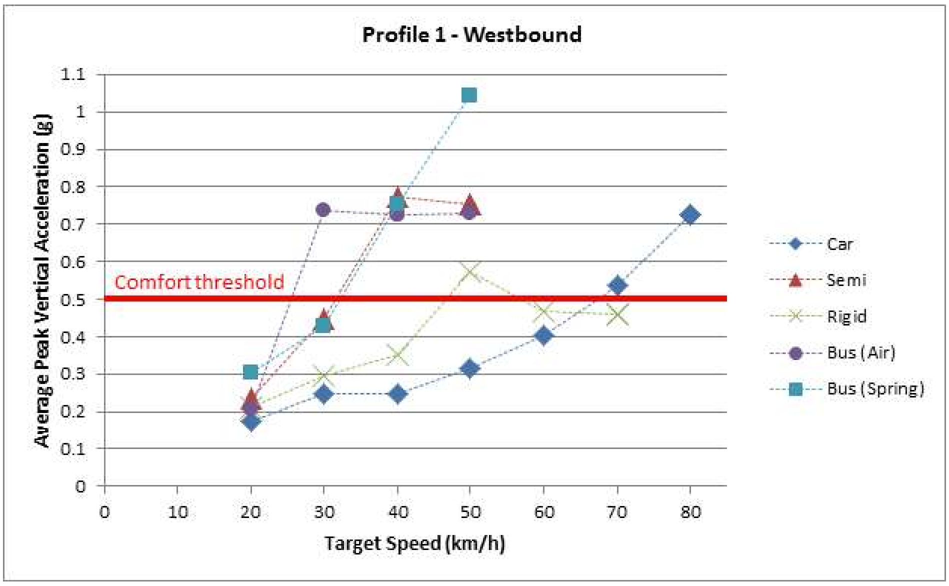


Figure 3. Average peak vertical accelerations measured at passenger seat for Profile 1 Safety Platform (travelling westbound)

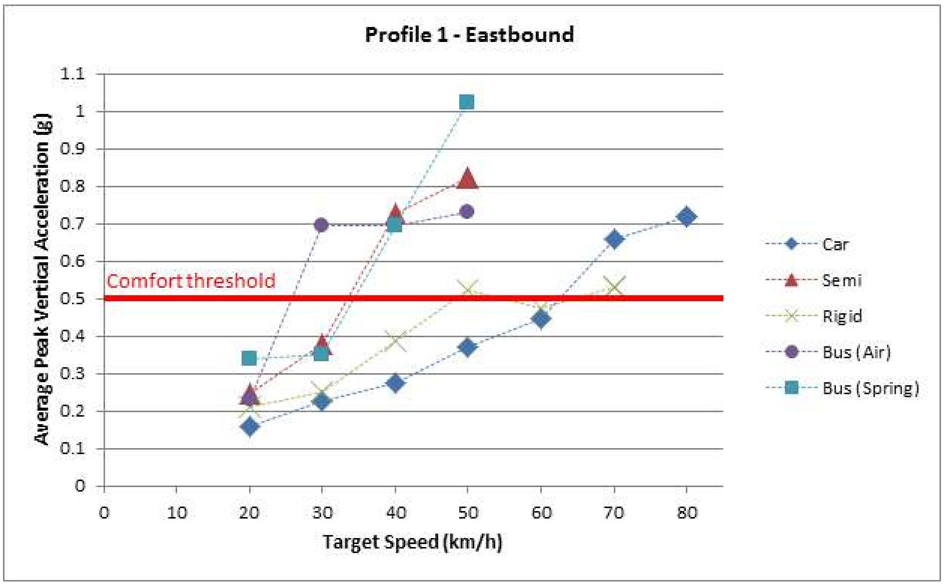


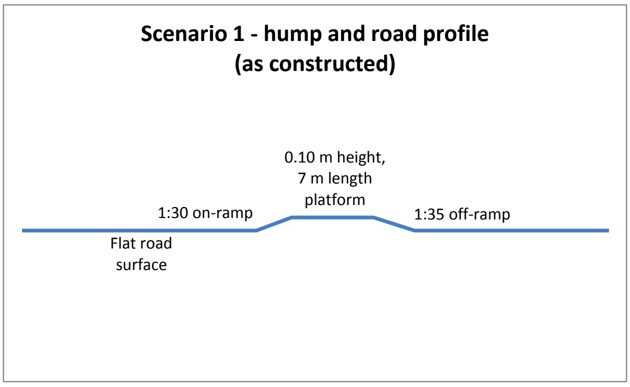
Figure 4. Average peak vertical accelerations measured at passenger seat for Profile 1 Safety Platform (travelling eastbound)

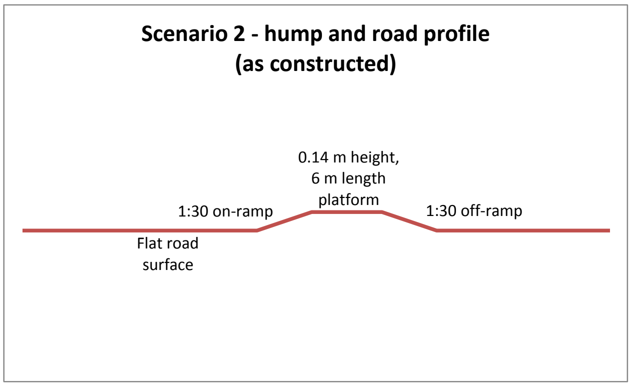
Previous work (Callaway et al. 2010) showed that Safety Platforms of this height and grade should have no adverse effects on vehicle stability in braking or wet weather conditions.

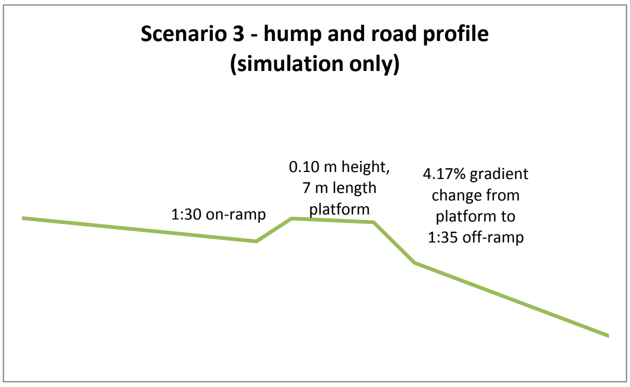
An additional assessment was required to determine comfort levels for different vehicle types when the Safety Platforms were installed under varying vertical displacement conditions. The two road conditions specified by VicRoads were the Profile 1 platform installed on a downhill slope with an off-ramp gradient change of 4.17%, and the platform tilted slightly to achieve an off-ramp gradient change of 2.86%.

The simulation model was set up based on the vertical acceleration test data collected from the trials at Gundog Lane, Belmont, and conducted using vehicle models constructed in Mathworks Simulink. The test data was also used to calibrate the models, allowing simulation of the operation of the tested two-axle vehicles on any combination of Safety Platform and road profile.

The simulation testing showed that should a downhill road gradient be present, maintaining a 4.17% gradient change (as in Scenario 3 in Figure 5) from the raised platform to the off-ramp is more likely than the other designs to allow maintenance of speed by larger vehicles while encouraging lower speeds in smaller vehicles.







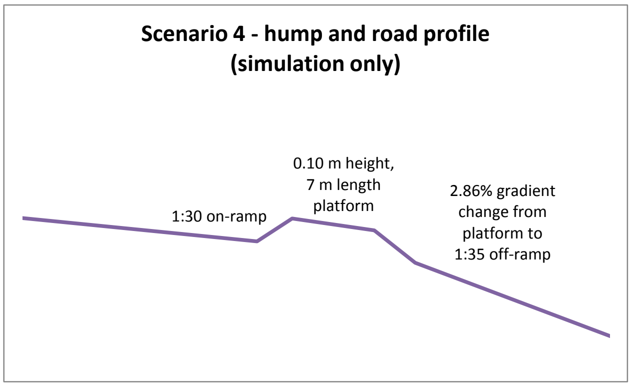


Figure 5. Scenarios used for modelling

The simulated road gradient (as seen in Scenarios 3 and 4) was found to generally lessen the vertical accelerations expected to be felt by passengers as a result of the Safety Platforms. Scenario 4 was consistently the most gentle of the four scenarios. Scenario 3 was generally closely matched with Scenario 1, which suggests that buses and other heavy vehicles would be able to achieve higher speeds over the platform without experiencing severe discomfort (i.e. closer to 50 km/h) whilst also limiting the speeds of smaller vehicles (particularly for Scenario 3). Scenarios 1 and 3 consequently had the smallest speed differentials compared to Scenarios 2 and 4. This is ideal for safety purposes.

Case Study – current status

VicRoads have selected a site to install the raised Safety Platforms in Victoria's west. The signalised intersection has a speed limit of 70 km/h along its primary road, and, as researched, the aim of the platforms is to reduce vehicle speeds down to 50 km/h through the intersection. The platforms are due to be installed in August 2015.

Discussion – issues relating to innovation

To get to this point in the process of introducing new infrastructure onto Victorian roads has required considerable dedication from VicRoads and has already taken a number of years to achieve. This highlights the need for a process, or some form of innovation framework to fast-track the process.

As previously mentioned, there are a number of reasons that some highly effective interventions are not introduced, even when these have been found to be highly effective in other countries. These include:

- a lack of knowledge regarding the treatment and its effectiveness
- lack of experience with treatment installation and maintenance
- issues regarding the transferability of some treatments and differing levels of effectiveness due to cultural/environmental influences
- concerns regarding legal liability should something go wrong
- concerns regarding public understanding and acceptability of the new treatment.

Road agencies should first be prudent in the selection of a new treatment. It should be rigorously tested and have documented safety benefits. A demonstration project can be an effective way of assessing a new treatment prior to wider rollout, much as VicRoads is doing now.

Based on the lessons from this current trial, as well as observation of similar approaches overseas, a methodological approach towards innovation should be adopted. It is suggested that this include the following:

- Identify the problem – in terms of target crash type, road user type and target locations.
- Identify possible solutions – including overseas examples or adaptations of existing treatments.
- Assess shortlist of solutions – research the treatments thoroughly to fully understand the likely beneficial safety outcomes as well as any other eaffects the intervention may have on the road network (e.g. changes in route capacity). This can include researching documented experiences from other road agencies, or the use of driver simulators to determine likely effects. Sometimes treatments can be installed in a controlled environment (such as the off-road trials done by VicRoads).
- Trial the selected solution – through a demonstration project in a controlled environment and specific context. This can be an effective way to test the intervention without the need for a full roll-out, as well as additionally strengthening institutional knowledge of the treatment and potential delivery partnerships.
- Monitor and evaluate the trial – ensuring that the outcomes are as predicted and that there are no unexpected (or unwanted) effects on road user safety or otherwise. The evaluation should comprise an assessment of the innovative treatment's cost effectiveness, including a comparison to the original 'do nothing' scenario.
- Roll out the solution on a wider scale – whilst continuing to monitor and evaluate the treatment sites. This should include crash analysis once sufficient data can be collected. Guidance documents should include design and operational information to ensure the treatment can be accurately reproduced each time.
- Inform others – including the public, and in particular the international road safety community. Regardless of whether the new treatment is effective or not, it is always important that this information is circulated for future reference. There are a number of road agency bodies that actively promote innovative treatments, including FHWA (2012).

It should be noted that guidelines are often slow to include innovative treatments, as it can take a number of years for these to be constructed and evaluated. Some Australian guides are still yet to incorporate the Safe System approach into their documents. Due to often infrequent updates of guidelines and a reluctance to change established practice, it is paramount that an evidence-based approach is used to facilitate the continual improvement and updates to guides.

Concluding remarks

It is acknowledged that achieving 'Vision Zero' will take more than the current selection of infrastructure treatments, and that there is a need for innovative and adapted solutions. The process to introduce new infrastructure into a road network is a complicated one, and this highlights the need for an innovation framework that takes an evidence-based approach. This should outline the process to identify, develop and fast track installation of treatments, but should also be tailored to each state road authority. Many potentially effective treatments have been identified from overseas, and these would most likely produce significant safety outcomes in Australia. Similarly, current research in Australia is focused on improvements to existing infrastructure to produce better reduction in fatal and serious injury. Without adoption of innovative infrastructure solutions it will be difficult to achieve Safe System outcomes.

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Curbing the Attention-Deficit: Influences of Task Demand During On-Road Driving

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Abstract

Previous research has indicated a critical role of task demand in determining driving outcomes amongst individuals with attention-deficit/hyperactivity disorder (ADHD). These findings have predominantly come from laboratory simulations, thus how task demand and arousal interact with attention to determine performance in real traffic situations is still unclear. The present study assessed driving performance amongst medicated and unmedicated ADHD drivers in a real driving task, using different traffic conditions to explore the effects of task demand on ADHD driving. Driver behaviour was recorded as participants navigated an on-road route in their own vehicles involving driving in urban, residential, rural, and highway environments. While unmedicated drivers employed fewer safe driving skills, and committed more inattentive and impatient driving errors, medicated drivers performed similarly to controls, attesting to the efficacy of stimulant medications. Greater task demands associated with manual as opposed to automatic driving; and urban as opposed to rural or highway environments were shown to improve attention and performance, particularly amongst unmedicated ADHD drivers. This is the first study to document such influences of task demand in real traffic. The present findings suggest that intervention strategies that focus on manipulating the level of task demand may be useful in improving driving outcomes amongst this established high-risk driving population.

Introduction

Attention-deficit/hyperactivity disorder (ADHD) is characterised by pervasive functional impairments related to inattention, hyperactivity and impulse control (American Psychiatric Association, 2013). In adulthood, this combination of symptoms has significant consequences for driving. ADHD is associated with repeat driving infringements; most commonly for excess speed, and high rates of illegal driving (Barkley, Guevremont, Anastopoulos, DuPaul, & Shelton, 1993; Woodward, Fergusson, & Horwood, 2000). Drivers with ADHD report more frequent engagement in risky driving behaviours, collisions, and are more likely to be found at fault in these collisions (Fried et al., 2006; Merkel et al., 2013). Furthermore, collisions that involve an ADHD driver are associated with greater harm or injury (Woodward et al., 2000). Drivers with ADHD also make more insurance claims, at a greater overall cost per claimant (Swensen et al., 2004).

Pharmacological treatment currently represents the most effective intervention for drivers with ADHD. Studies suggest medication can lead to improvements in basic driving skills, fewer instances of inattention and impulsivity, and reduced involvement in erratic driving and collisions (Cox et al., 2012; Sobanski et al., 2013). These studies however tend to be exclusively outcome driven, offering comparisons of performance pre- and post-treatment without reflection upon the cognitive functions underlying risk. As a result, attributes of the driving experience that can both maintain and impede sustained attention; an innate feature of ADHD, remain relatively uncharted (Reimer, Mehler, D'Ambrosio, & Fried, 2010).

Sustained attention is critical for coherent cognitive function (Lavie, 2005). Research has shown that an individual's ability to sustain attention is largely jeopardised when demand is low, resulting in impaired vigilance and error prone performance (Thiffault & Bergeron, 1995; Wilde & Stinsson, 1983). In the case of driving, monotonous environments such as rural or highway roads that are repetitive may also encourage cognitive underload, thus impairing attention and performance, and increasing the risk of adverse road safety outcomes (Cox et al., 2006; Thiffault & Bergeron, 1995; Reimer et al., 2010). Given that individuals with ADHD require an elevated threshold of stimulation for sustained attention, compromises to attention and performance associated with low demand, monotonous tasks are accentuated amongst this population (Forster, Robertson, & Jennings, 2014). In a simulated driving study, participants with and without ADHD completed a secondary hands-free phone task introduced during high-demand urban and low-demand highway driving. While ADHD and control group performance was similar under the high demand condition, introduction of a secondary cognitive task was shown to impair ADHD driver performance considerably during low demand driving (Reimer et al., 2010). In a similar study, Biederman et al. (2012) found that ADHD drivers were significantly more likely to collide with a hazard presented in the periphery than were controls during dull, highway driving.

Outside the context of driving, researchers have shown that ADHD attention and performance may be improved by increasing the cognitive demands of a task. For example, in a letter search task, distractor stimuli were found to significantly impair the response times of ADHD participants compared to controls. By increasing the size of the search set however, distractor interference was reduced, resulting in improved response times amongst ADHD participants (Forster et al., 2014). Similarly, moderate auditory white noise has been shown to increase demand in the classroom, impairing control's performance on a cognitive challenge, but improving the performance of ADHD participants compared to a baseline, no-noise condition (Söderlund, Sikström, & Smart, 2007).

To date, just one study has examined an intervention amongst ADHD drivers where a high demand condition is introduced to improve driver attention and performance (Cox et al., 2006). Cox and colleagues (2006) compared the performance of 10 adolescent males with ADHD during simulated driving in both automatic and manual transmission modes. During manual driving, self-reports of improved attention to the driving task, and objective improvements in driving were found compared to automatic driving (Cox et al., 2006). Increased task demand is proposed to underlie the efficacy of this intervention, as effective operation of a manual vehicle requires more frequent attention to the driving process (Cox et al., 2006). Participants must monitor and control their speed and tachometer readings using the clutch, accelerator, brake, and gear stick, thus sustaining attention to the driving task, and evading the distractibility effects experienced during low demand driving.

The objective of the present study was threefold: to assess the driving performance of medicated and unmedicated ADHD drivers in a real driving task; to assess the effect of task demand on ADHD driving by assessing performance across different traffic conditions and vehicle transmissions; and to compare self and observer reported measures of driving performance and behaviour. Although simulator studies have been used to introduce secondary distractor tasks and risk events, and to manipulate demand conditions, the effects of naturally occurring driving events are yet to be explored. Thus, in the present study, participants navigated driving routes incorporating rural, urban, residential, and highway environments in their own automatic or manual transmission vehicles, while measures of attention and performance were collected.

Method

Participants

A total of 44 licenced drivers were recruited to participate in the study. Control group drivers (*n* = 17) without a diagnosis of ADHD or history of taking stimulant medication were recruited through advertisements on community and university notice boards. Drivers formally diagnosed with ADHD drivers were recruited through social media forums, and presentations at ADHD Adult group meetings. Those taking a prescribed stimulant treatment constituted the Medicated ADHD group (*n* = 15), and were instructed to take their medication as normal on the day of assessment. Drivers who had not taken medication for their ADHD in the month prior to and during participation in the study were designated as being in the Unmedicated ADHD group (*n* = 12). Recruitment and testing protocols were approved by the School of Psychology Human Research and Ethics Committee at the University of Waikato.

The 17 Control group drivers (11 female, 6 male, aged 19 to 57) reported 12 to 436 months of licensed driving experience, and drove between 30 and 500 kilometres a week. Control group symptom scores fell within the normal range on the Conners' Adult ADHD Rating Scale (CAARS–S:L; Conners, Erhardt, & Sparrow, 1999)**.** The 15 Medicated ADHD drivers (8 female, 7 male, aged 17 to 67) reported 8 to 452 months of licensed driving experience, and drove 20 to 500 kilometres a week. The Unmedicated ADHD group was made up of 12 (9 male, 3 female) drivers aged between 21 and 65 who reported 17 to 564 months of licensed driving experience, and drove between 10 and 500 kilometres a week. ADHD symptom severity was not found to differ between drivers from the medicated and unmedicated ADHD groups. Both group *t*-score means fell above the 98th percentile for DSM-IV ADHD Symptoms Total, indicative of severe ADHD symptomology. The ADHD groups were made up of a similar proportion of predominantly inattentive, predominantly hyperactive-impulsive, and combined subtype diagnoses. There were no significant group differences in age, driving experience, driving license type, average weekly mileage, or vehicle transmission. There was, however, a significant gender imbalance across the three groups, due to a preponderance of male drivers in the Unmedicated group ($F(2, 41) = 12.96$, $p = .002$).

Driving scenarios

A naturalistic method was employed to collect on-road driving performance data. Participants drove predetermined driving routes in their own car while accompanied by an observer. A total of 10 driving routes were developed, each containing urban, residential, rural and highway conditions to represent different levels of environmental demand. The driving routes were approximately 10 to 15 km in length, and required 25 minutes to complete. At 12 locations throughout each route, participants performed one of five assessed driving tasks: right turn at a roundabout or into a side street, left or right turn at a controlled intersection, or lane change left or right. The driving routes were designed to include each of the tasks at least twice. Video was recorded throughout each drive, capturing the driver's face, hands, speedometer, and the view ahead and to the right of the driver.

Driving performance measures

To score the specific driving tasks, performance was partitioned into eight component measures of driving performance: observation, passenger comfort, following distance, signalling, gap selection, hazard detection, hazard response, and speed, according to New Zealand driver licence testing standards (NZTA, 2012). These eight performance measures were calculated on a scale of 0 to 100. In addition, an overall measure of driving performance was formed from the mean of the eight components. Finally, performance scores for urban, residential, rural, and highway driving were calculated by averaging the component measures taken from those sections of each driving route.

Three error measures were also calculated for each drive: inattentive, impatient, and aggressive errors. An inattentive error described a lapse in driver attention, such as a failure to signal or give way, or delayed recognition of driving hazards. Impatient errors were violations that lacked a malicious or aggressive aim, and included impulsive and impatient on-road behaviours such as speeding, weaving between lanes, and running red lights. Aggressive errors were interpersonally aggressive and hostile in nature, such as cutting off vehicles or excessive tailgating (Lawton, Parker, Manstead, & Stradling, 1997).

Scoring of the performance measures was initially conducted by an in car observer who was not blinded to condition. Two independent, blind-observers later scored the video footage of 5 randomly selected participants from each group as they completed 5 driving tasks. The blind observers were instructed to read carefully over the scoring guide, and to replay the video footage as necessary to score each item. Cronbach's alpha was calculated using this data to determine agreement between observers. There was substantial agreement between the blinded observers and the in car observer, $\alpha = .895$ (95% CI = .841 to .931), $p < .001$.

Procedure

Drivers who expressed an interest in the study were provided an information sheet outlining the research background and procedure. Details related to the use of a video camera during the driving segment of the test were provided, and participants were encouraged to ask questions before reviewing and signing the consent form. Driving was assessed in the participant's own vehicle to minimise errors attributable to unfamiliarity. Drivers were instructed to drive as they normally would whilst directions were provided by the researcher. The first 5-minutes of the driving route served as a preliminary test of the basic driving skills required to safely complete the on-road tasks. All participants successfully passed the preliminary safety check, proceeding on to the assessed part of the drive. Participants received a $20 gift voucher as reimbursement.

Statistical analyses

Group differences in overall driving performance and errors were analysed using one-way ANOVAs. This was followed by Bonferroni-adjusted pairwise comparisons between the three groups. To test the effect of environmental demand, a 3 (Group) X 4 (Environment) MANOVA was used to examine group differences in driving errors across the four types of driving environment; rural, urban, residential, and highway. Because the number of assessment opportunities differed across these environments, overall performance scores were standardised within each of the four driving environments by subtracting the overall mean (across environments) from each score and dividing by the standard deviation. The effect of vehicle transmission type was tested by comparing the performance of participants who drove vehicles with either a manual or automatic transmission. The comparisons were made separately for each group using independent *t*-tests.

Results

Driving performance

Table 1 shows the group means scores for observer-reported measures of on-road driving performance and engagement in driving errors. Compared to the Unmedicated group, Medicated ADHD drivers selected significantly safer gaps in traffic (p = .017), drove at safer speeds (p = .028), and scored more highly on an overall measure of performance (p = .025). Control group drivers also maintained safer speeds than Unmedicated drivers (p = .036) and tended to identify hazards in the driving environment more effectively (p = .070), although responses to identified hazards were often less effective than those of Medicated (p = .034) and Unmedicated ADHD drivers (p = .070).

Table 1. On road driving performance by group

	Control (n = 17)	Medicated (n = 15)	Unmedicated (n = 12)	F(2, 41)	p	η_p^2
Performance						
Observation	91.80 (1.99)	94.26 (1.49)	86.69 (2.81)	3.116	.056	.303
Comfort	82.90 (4.10)	90.91 (1.31)	78.60 (5.23)	2.533	.092	.261
Following distance	92.53 (1.91)	95.44 (2.41)	85.55 (5.60)	2.115	.134	.225
Signalling	92.35 (2.72)	85.49 (3.31)	81.37 (4.14)	2.542	.092	.262
Gap selection	94.34 (1.40)	97.16 (0.98)	87.85 (3.87)	4.326*	.020	.370
Hazard detection	94.32 (2.26)	94.06 (2.33)	86.08 (3.11)	3.166*	.050	.306
Hazard response	78.54 (5.24)	94.35 (2.61)	85.80 (4.57)	3.440*	.042	.322
Speed	86.03 (2.28)	86.91 (2.22)	74.17 (5.16)	4.465*	.018	.376
Overall	88.10 (1.91)	91.84 (1.32)	83.26 (3.19)	3.721*	.033	.332
Errors						
Inattentive	1.47 (0.26)	1.50 (0.29)	2.83 (0.49)	4.797*	.013	.384
Impatient	0.71 (0.27)	0.67 (0.24)	2.92 (0.70)	9.095***	< .001	.519
Aggressive	0.47 (0.26)	0.23 (0.11)	1.42 (0.70)	2.473	.097	.251
Total	2.65 (0.49)	2.40 (0.47)	7.17 (1.41)	10.301***	< .001	.545

Note. Mean (SE). $^*p < 0.05$. $^{**}p < .01$. $^{***}p < .001$. Effect size (η_p^2) = Partial Eta Squared.

Significant effects of group were also revealed for inattentive, impatient, and total driving errors (see Table 1). Unmedicated ADHD drivers engaged in significantly more inattentive (p = .020; p = .028), impatient (p = .001; p = .002), and total driving errors (p = .001; p = .001) than drivers from the Control and Medicated ADHD groups, respectively.

Environmental demand

The effect of driving environment demand (i.e., high demand urban and residential driving, and low demand rural and highway driving) on the rate of driving errors was then explored for each group. A 3 (Group) x 4 (Environment) MANOVA was calculated across the three error measures. This revealed a significant multivariate interaction between group and environment; *Wilk's lambda* = .798, F(18, 458) = 2.122, p = .005. Significant effects of environment on Medicated drivers' inattentive; F(3, 56) = 4.624, p = .006, η_p^2 = .409, and impatient errors; F(3, 56) = 3.795, p = .015, η_p^2 = .371 were shown. For Unmedicated drivers, effects of environment were shown for inattentive; F(3, 44) = 6.363, p = .001, η_p^2 = .516, and aggressive errors; F(3, 44) = 3.139, p = .035, η_p^2 = .369.

As shown in Figure 1, attention to the driving task was best during high demand, urban driving. As environmental demand decreased, drivers experienced increased difficulty attending to the driving task, resulting in more frequent inattentive errors. Significantly higher rates of inattentive errors were observed during highway driving compared to driving on residential (p = .021; p = .027) and urban (p = .006; p = .007) roadway amongst Medicated and Unmedicated drivers, respectively. Rural driving was also associated with more frequent inattentive errors amongst the Unmedicated group compared to residential (p = .044), and urban (p = .013) driving.

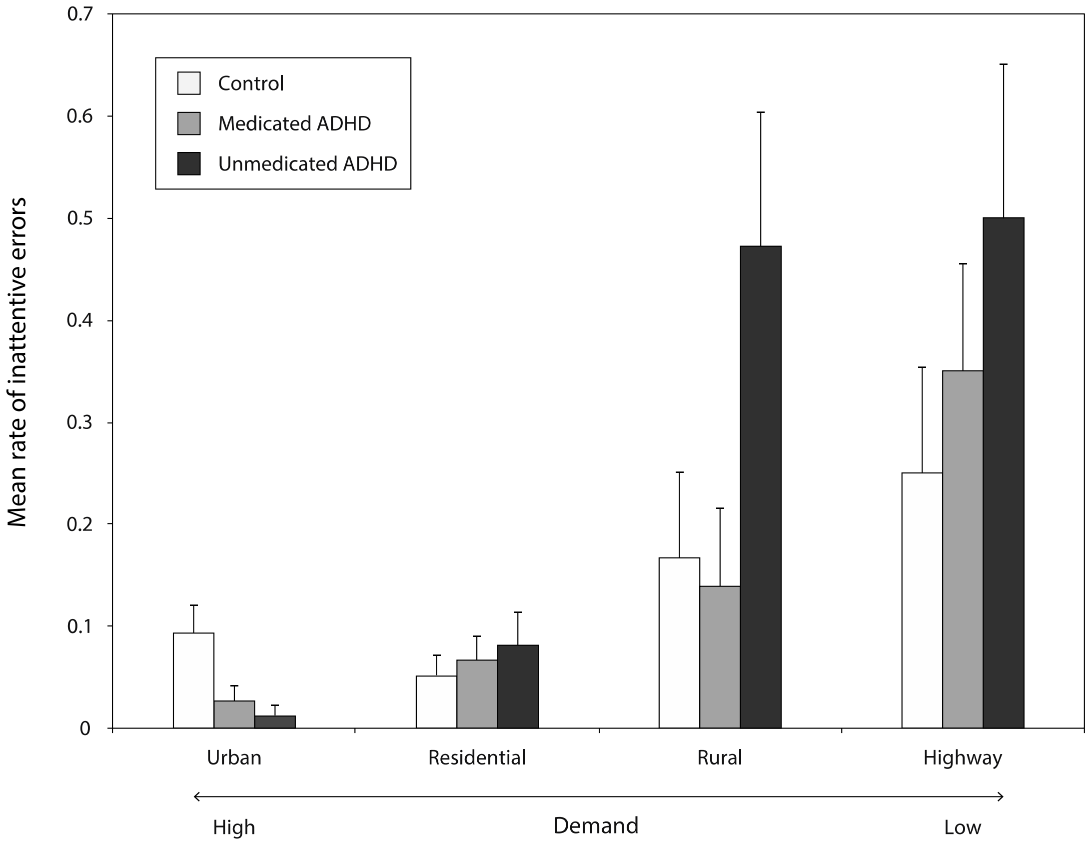

Figure 1. Group mean rate of inattentive errors by driving environment. Error bars show 95% confidence intervals.

Unlike inattentive errors, impatient and aggressive driving errors were observed very rarely during low demand, rural driving for all three driver groups. While Medicated drivers engaged most in impatient errors during highway driving (M = 0.21, SD = 0.33), no impatient errors were observed on rural roadway (M = 0) (p = .014). Unmedicated ADHD drivers tended to commit aggressive errors during urban driving (M = 0.23, SD = 0.39), but not during driving in rural (M = 0) (p = .084) and residential environments (M = 0) (p = .084).

Transmission

The effect of vehicle transmission on performance was explored for each group by comparing the performance of participants who drove an automatic vehicle with that of manual transmission drivers. No significant effect of transmission was revealed amongst the Control group. Manual drivers from both the Medicated and Unmedicated ADHD groups performed on average better than automatic drivers from the same group across all measures of driving performance (see Table 2). Compared to automatic drivers (n = 9), manual drivers (n = 6) from the Medicated ADHD group scored significantly higher on measures of hazard detection and overall performance. Manual driving was also associated with better use of signals and greater levels of passenger comfort, however these differences were not statistically significant. Manual drivers (*n* = 6) amongst the Unmedicated ADHD group maintained significantly safer following distances than automatic drivers (*n* = 6), and tended to perform better on measures of signalling and overall performance.

Table 2. ***Medicated and Unmedicated ADHD group driving performance by vehicle transmission***

	Group	**Automatic**	**Manual**	***t***	***p***	**Effect size (*r*)**
Observation	Medicated	92.68 (2.07)	96.73 (1.10)	-1.50	.158	.383
	Unmedicated	84.79 (4.67)	89.32 (1.77)	-0.91	.392	.313
Comfort	Medicated	87.61 (2.24)	93.23 (1.57)	-1.84	.088	.457
	Unmedicated	75.29 (5.93)	83.22 (9.86)	-0.73	.481	.226
Following Distance	Medicated	94.81 (3.61)	97.13 (2.04)	-0.98	.634	.134
	Unmedicated	75.26 (7.47)	100.00 (0.00)	-3.31*	.016	.724
Signalling	Medicated	80.39 (4.27)	93.17 (3.67)	-2.11	.055	.504
	Unmedicated	76.24 (5.72)	88.54 (4.72)	-1.56	.151	.442
Gap Selection	Medicated	94.82 (1.95)	98.33 (1.07)	-1.37	.195	.416
	Unmedicated	86.27 (5.28)	90.04 (6.17)	-0.46	.653	.145
Hazard Detection	Medicated	87.06 (4.78)	98.62 (1.38)	-2.32*	.044	.469
	Unmedicated	85.47 (3.78)	86.92 (5.80)	-0.22	.831	.069
Hazard Response	Medicated	92.12 (3.29)	95.83 (4.17)	-0.70	.494	.192
	Unmedicated	83.21 (6.83)	89.44 (5.85)	-0.65	.528	.203
Speed	Medicated	86.73 (3.26)	89.35 (2.99)	-0.56	.587	.153
	Unmedicated	69.86 (6.60)	80.20 (8.32)	-0.99	.347	.319
Overall	Medicated	89.53 (1.74)	95.32 (1.02)	-2.50*	.026	.635
	Unmedicated	79.54 (4.40)	88.46 (3.87)	-1.44	.179	.416

Note. Mean (SE). *$p < 0.05$. Medicated ADHD $df = 13$, Unmedicated ADHD $df = 10$.

Discussion

This is the first known study to investigate ADHD driver performance as a function of naturally occurring influences of demand in real traffic. In keeping with the predicted outcomes, the driving of Unmedicated ADHD participants was significantly worse than that of drivers from the Control and Medicated ADHD groups. Unmedicated drivers committed more errors on the road, most commonly as a result of inattention or impatience.

Relative to the Medicated group, Unmedicated ADHD drivers demonstrated poor observation and gap selection skills, and more frequently travelled at speeds in excess of the speed limit. A tendency for poorer performance compared to Controls was also observed. There was one exception to this trend. While Controls tended to identify hazards effectively, responses to those hazards were often less effective than those of ADHD drivers. This finding might be related to previous findings related to ADHD responsiveness to increased task load (Reimer et al., 2010); task demand may also increase in potentially threatening situations, resulting in more effective hazard responses amongst drivers with ADHD.

Significant effects of both driving environment and of vehicle transmission were revealed. Attention to the driving task was best during high demand, urban driving. As environmental demand decreased, however, Unmedicated ADHD drivers experienced increased difficulty attending to the driving task, resulting in more frequent inattentive errors. Supporting the findings of Cox and colleagues (2006), heightened task demands associated with the effective operation of a manual vehicle also encouraged improved performance relative to drivers of automatic vehicles. Several participants even noted their preference for driving vehicles with a manual transmission because it was more engaging, or because their mind would wander less. Manual driving was associated with better hazard detection skills, greater levels of passenger comfort, and more appropriate use of indicators amongst Medicated ADHD drivers, and safer following distances and more appropriate use of indicators amongst Unmedicated ADHD drivers.

The results should be considered in light of several limitations. Difficulty recruiting diagnosed ADHD drivers meant that gender could not be balanced between groups. As a result, the Unmedicated ADHD group consisted predominantly of male drivers (75%). The recruited sample is a direct reflection however of those who volunteered to participate, and is consistent with the gender discrepancy in rates of referral and diagnosis (Biederman, Faraone, Monuteaux, Bober, & Cadogen, 2004; Coles, 2012). Secondly, differences in task demand as a function of driving environment were assumed, but not validated. Finally, as participants completed the driving task in their own vehicle, a repeated measures design where participants drive both a manual and automatic vehicle was not feasible. Comparisons were instead conducted between drivers of automatic vehicles and drivers of manual vehicles to explore the effect of vehicle transmission on performance, thus sample size may limit the reliability of these comparisons.

Despite these considerations, this study has established several important influences of ADHD driver performance seldom explored in research to date. Most significantly, influences of demand within the driving experience were shown to impact attention amongst ADHD drivers. These findings impart that individuals with ADHD are capable of resisting distraction when a primary task is perceived to be sufficiently compelling, and that demand can be manipulated to encourage such outcomes (Forster et al., 2014; Reimer et al., 2010; Söderlund et al., 2007). Practical intervention strategies that are able to effectively engage this finding may present a plausible means of relieving the undermining impacts of distraction on ADHD driver performance, thus improving outcomes amongst this established high risk driving population. Recommending individuals with ADHD choose to drive vehicles with a manual transmission represents such an intervention, particularly for adolescents who are considering purchasing their first vehicle (Cox et al., 2006). Low demand driving environments may result in impairments of alertness and vigilance that encourage collisions, independent of drowsiness, therefore means of alleviating compromised attention during periods of monotony at the wheel should be investigated (Thiffault & Bergeron, 1995).

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An explorative analysis of pedestrian situation awareness at rail level crossings

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Abstract

Pedestrian safety at rail level crossings (RLXs) is a concern for governments and the community. There is sparse published literature, however, that has investigated pedestrian situation awareness when negotiating RLXs. This paper presents the findings from an exploratory study of pedestrian situation awareness at RLXs. Fifteen participants took part in a naturalistic study in which participants walked a pre-defined route in one of three urban environments, each of which incorporated two RLXs. Whilst walking the route participants wore video recording glasses and provided 'think aloud' verbal protocols describing the cognitive processes and decision making underpinning their behaviour. Analysis of the verbal protocols provided during the approach and traversal of the RLX was conducted using content analysis software as well as through manual analysis of the data. The analysis identified that pedestrian situation awareness was most commonly underpinned by concepts such as the 'railway crossing', the 'train' and other 'pedestrians'. Interestingly, concepts such as 'bells', 'flashing lights' and the ‘pedestrian gate' were not prominent. This may reflect that most participants did not encounter the RLX when a train was approaching. However, concepts around checking for the train were prominent suggesting that many pedestrians may not simply rely on automatic warnings, but use their own judgement to make a decision about when it is safe to cross a RLX. Further findings, implications for RLX design, limitations and future research directions will be discussed.

Introduction

Collisions involving pedestrians being struck by trains at rail level crossings (RLXs) are a public safety concern in Australia and internationally. The most recent statistics available show that, in the 10 year period between 2002 and 2011, 92 pedestrians were struck by trains at RLXs in Australia (ATSB, 2012). The majority of these collisions (51) occurred in the state of Victoria, with other states and territories experiencing between zero and 16 collisions over the same time period. In Victoria, collisions between trains and pedestrians at RLXs resulted in 17 fatalities and six serious injuries in the five year period between 2009 and 2013 (TSV, 2014). Further, statistics indicate that reductions in collisions being experienced in relation to motor vehicle-train collisions is not reflected in the pedestrian-train collision rate (ATSB, 2012; Metaxatos & Sririj, 2013; Stefanova et al., 2015). Finally, it has been identified that there is a lack of research into the reasons behind pedestrian-train collisions (e.g. Freeman, Rakotonirainy, Stefanova & McMaster, 2013; Read, Salmon & Lenné, 2013).

Situation awareness, the ability to develop and maintain an understanding of ‘what is going on’, is important to support safe decision making at RLXs (Salmon, Lenné, Young & Walker, 2013). If pedestrians are not aware of important elements in the environment or do not understand the relevance of information and cues, they will be more susceptible to errors or poor decisions. Diminished situation awareness has been implicated in RLX crashes involving drivers (e.g. Office of the Chief Investigator, 2007) and has been emphasised as required to avoid situations of unintentional non-compliance by drivers with RLX warnings (Salmon, Lenné, Young & Walker, 2013). While there is evidence that intentional violations by pedestrians of warnings at RLXs are more prevalent than unintentional errors (Freeman & Rakotonirainy, 2015), situation awareness remains important in cases where pedestrians have chosen to breach the road rules as they may not be aware of important information in the environment which could put them at risk (for example, they may be aware of a train approaching, but not aware that another train is also approaching from the other direction).

While the literature on pedestrian situation awareness and decision making at RLXs is limited, some findings are emerging. Beanland and colleagues (2013) investigated pedestrian, driver, cyclist and motorcyclist decision making at RLXs via a daily survey about RLX encounters, incorporating questions based on the critical decision method probes. Pedestrians most often reported that the bells ringing was their first alert to the presence of a train and that audible warnings were the most important piece of information when deciding whether or not to cross. In addition, pedestrians reported that the sight of a train was the most important factor that influenced their decision to stop or proceed across the RLX. However, for drivers, visual information such as the flashing lights were the most influential factors informing decision making. Compared to other road users (drivers, cyclists, motorcyclists) pedestrians were statistically significantly more likely to report speeding up when the warnings activated to cross before the train arrived at the RLX. These findings reinforce the importance of considering pedestrian decision making at RLXs specifically, rather than relying on findings from studies of drivers.

In another study, the data from Beanland et al.'s (2013) daily survey study were employed to develop decision ladder models to describe and compare decision making processes during compliant and non-compliant encounters with RLXs (Mulvihill, Salmon, Lenné, Beanland & Stanton, 2014). This work compared compliant and non-compliant crossings by pedestrians and found that pedestrians who crossed in a compliant manner were more likely to report having been alerted by the flashing lights than those crossing in a non-compliant manner. Those who crossed in a non-compliant manner were more likely to report they used information about the location of the train in making their decision, suggesting that non-compliant pedestrians go beyond the warnings to gather information regarding the position of the train.

Stefanova and colleagues (2015) conducted focus groups with pedestrians in Brisbane and analysed the factors influencing their decision making based on crossing experiences described by participants. The study found that factors relating to the pedestrian themselves (e.g. their past knowledge and experience) as well as factors associated with the physical environment (e.g. the RLX and station environment), the social environment (e.g. motorised users' behaviour) and the organisational level (e.g. rail traffic planning and procedures which affect train stopping patterns) were influential in determining pedestrian behaviour.

This literature provides an interesting perspective on pedestrian behaviour at RLXs. However, it is notable that the data in all studies was obtained post users negotiating the RLX. An important gap in the literature then is research adopting naturalistic methods to obtain data in-situ whilst pedestrians are engaged in RLX tasks. Using situation awareness as a lens through which to examine pedestrian behaviour enables the use of semi-naturalistic methods, such as concurrent verbal protocols whereby participants 'think aloud' while conducting tasks, to examine cognition at RLXs. Such approaches have previously been applied to understand driver situation awareness at RLXs (e.g. Salmon, Lenné, Young & Walker, 2014) and to investigate pedestrian situation awareness at road intersections (e.g. Salmon, Lenné, Walker, Stanton & Filtness, 2014). However, they have not previously been applied to understand pedestrian situation awareness and decision making at RLXs. The aim of this paper is to explore pedestrian situation awareness at RLXs using semi-naturalistic methods, including concurrent verbal protocols, to identify findings that could be applied to improve pedestrian safety in this context.

Method

Prior to data collection commencing, approval for the research was obtained from the Monash University Human Research Ethics Committee.

Participants

Participants were recruited through a weekly online university newsletter, through pamphlets distributed at local community centres and businesses and via advertisements on social media platforms. Fifteen participants (6 males, 9 females) were recruited to take part in the study (five at each study location). Participants were aged between 19 years and 62 years (M = 34.2 years, SD = 14.2 years).

A paper-based demographic questionnaire was completed by participants. A laptop computer was used to display a training video showing a forward facing view of a pedestrian walking on a footpath in an urban environment to enable the researcher to demonstrate the verbal protocol methodology and enable participants to practice and gain feedback from the researcher.

Three RLX locations in the south-eastern suburbs of Melbourne, Victoria were selected by the researchers and for each, a pre-determined route that incorporated two RLXs (once on each side of the road). The locations were Centre Road in Bentleigh, McKinnon Road in McKinnon and Murrumbeena Road in Murrumbeena. All sites had automatic pedestrian gates and were adjacent to train stations and road RLXs (with flashing lights and boom barriers installed). Figure 1 shows the approach view for one RLX at each study location. The RLX at Bentleigh, in addition to the standard warnings, had red man standing signals for pedestrians (similar to those provided at road crossings but with no green phase, shown in Figure 1 in the deactivated state as no train is approaching).

Centre Road, Bentleigh

McKinnon Road, McKinnon

Murrumbeena Road, Murrumbeena

Figure 1. Images of the approach to three of the RLXs used in the study

The routes were designed to be completed in approximately 20 minutes, given differences in normal walking speeds. Route completion times for Bentleigh were between 10 minutes 35 seconds and 15 minutes 46 seconds; for McKinnon were between 14 minutes 05 seconds and 23 minutes 54 seconds; and for Murrumbeena were between 9 minutes 51 seconds and 15 minutes 05 seconds. All participants wore Imging HD video recording glasses and a microphone and dictaphone to record the forward view and their verbal protocols.

Procedure

Participants met the researcher at a public place near to the study site for which they had been recruited. Participants were provided with an information sheet broadly describing the aims of the research and completed a consent form. Participants were told that the research was investigating pedestrian behaviour in urban environments. Next, participants were provided with instructions on how to provide concurrent verbal protocols and they practised providing concurrent verbal protocols while watching a video recording of a pedestrian's perspective of walking in an urban environment. The researcher provided feedback to the participant regarding the quality of their verbal protocols until it was felt they were able to provide protocols of sufficient quality for the study. Participants were then shown the pre-determined route and asked to memorise it. When participants were comfortable with the verbal protocol procedure and the route the recording equipment was fitted and activated. Participants then negotiated the study route alone whilst providing a continuous verbal protocol. Once participants had completed the route, which was a loop, they met the researcher back at the point of origin.

Data analysis

The verbal protocols were transcribed verbatim using Microsoft Word. The verbal protocols provided by participants relating to the RLX were extracted from the overall dataset. These included verbalisations given on approach to each RLX from either the point at which RLX-related concepts were first mentioned or when the participant had reached the fencing that funnels pedestrians in towards the RLX pedestrian infrastructure. Verbalisations provided during the traverse of the RLX were included in the extracted data set until the participant was at a point where they had exited the RLX. One participant made no verbalisations during the RLX encounters, meaning that the final dataset contained verbalisations from 28 RLX encounters (each of 14 participants traversed two RLXs). In 8 encounters, participants experienced the RLX warnings operate for the approach of a train (a '*train coming*' encounter) and in the remaining 20 the RLX warnings were not activated (a '*no train coming*' encounter). It should be noted that in *no train coming* encounters there may have been a train visible to the participant in the distance).

The verbal protocol data were analysed in two ways. Initially, the text from the transcripts was uploaded into the Leximancer content analysis software which analyses relationships between concepts from an objective perspective using the natural language of the participants. The software uses algorithms to determine the key concepts and their relationships based on position within the text. Secondly, to gain a deeper understanding of the individual concepts and their meaning, the transcripts were reviewed and key concepts coded using NVIVO software. Concepts identified from participants' verbalisations included either references to information in the environment or to actions (physical and cognitive) being undertaken or planned by the participant. For example, the utterance 'Moving over for a pedestrian' was coded as containing an information concept 'pedestrian' and an action concept 'moving over'. Here the natural language of participants was maintained so far as possible, however categorisation was undertaken to classify similar concepts to ensure a coherent data set. For the *train coming* encounters, 267 concepts were identified in the verbal protocols and for the *no train coming* encounters 316 concepts were identified.

Results

Objective analysis

The results from the objective analysis of the data are provided in the concept maps shown in Figures 2 and 3. The figures show concepts mentioned by participants according to the relationships uncovered in the text. The larger the node (circle shown behind the concept name), the more frequent or important the concept was in the text. The shorter the links between nodes, the more closely related the concepts.

Figure 2 shows the concept map for participant verbalisations during *train coming* encounters. It indicates that the concepts ‘signal’, ‘pedestrian’, ‘crossing’, ‘train’, ‘walking’ and ‘wait’ were the most important within the text. The concepts associated with signals (i.e. flashing lights or red man standing signals) are also interesting, with references to looking at signals, checking the signals and having noticed the signal or attention being drawn to them. However, the concept of signal is not linked to the concept of ‘train’. It would appear instead that the concepts of ‘bells’ and the ‘gate’ were more often associated with the train in pedestrian’s situation awareness. Interestingly, the concepts of ‘boom’ and ‘gates’ (i.e. boom gates) was relatively frequent in the data, even though boom gates are not intentionally provided as a signal for pedestrians.

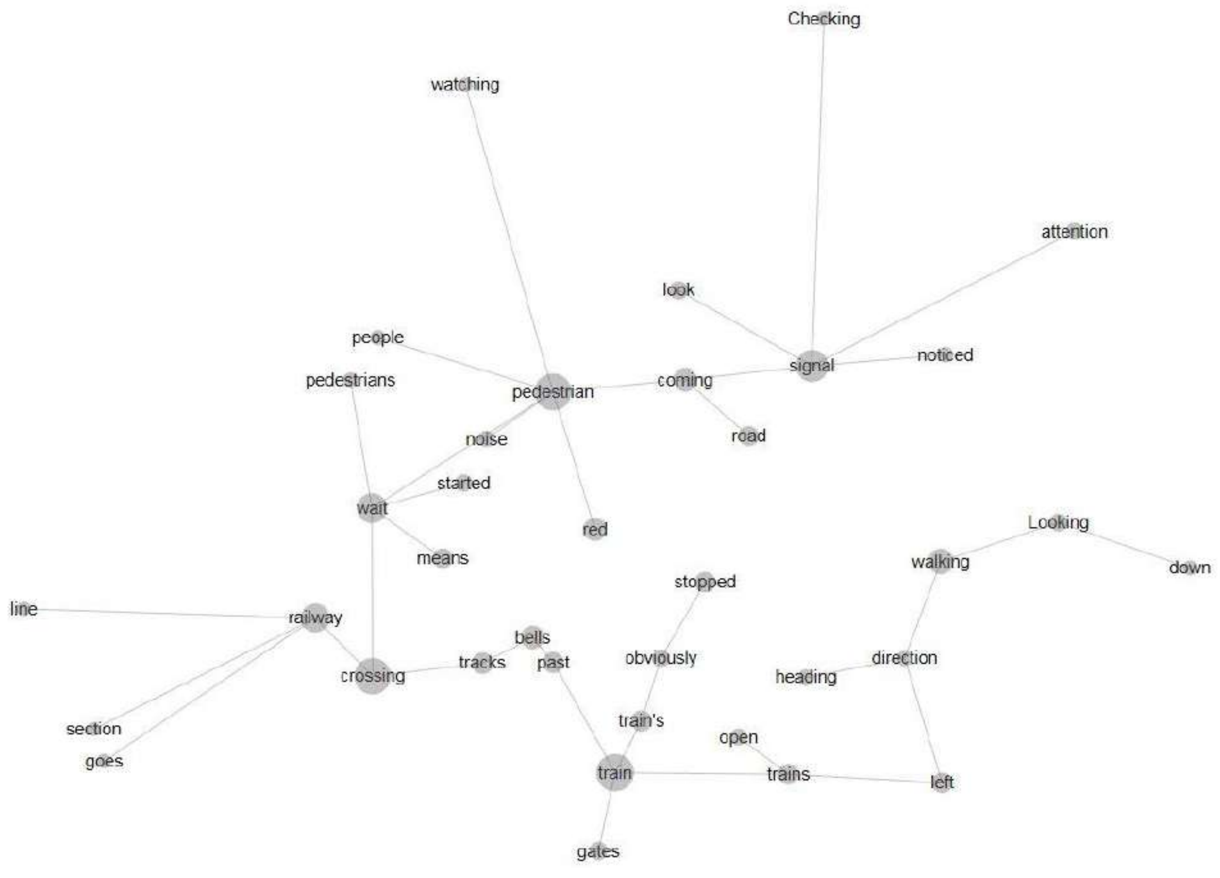

Figure 2. Concept map of pedestrian situation awareness in ‘train coming’ situations

Figure 3 shows the concept map for data collected during *no train coming* encounters. Here the concepts of ‘railway’, ‘crossing’, ‘checking’, ‘check’, ‘trains’ and ‘coming’ were most important within the verbalisations. In comparison to Figure 2, there appeared to be more uncertainty in this concept map, with concept such as ‘probably’, ‘caution’ and ‘sure’ being present. Further, in both concept maps checking was generally associated with the signals, however in Figure 3 checking is also associated with whether trains are ‘coming’ and with ‘lights’.

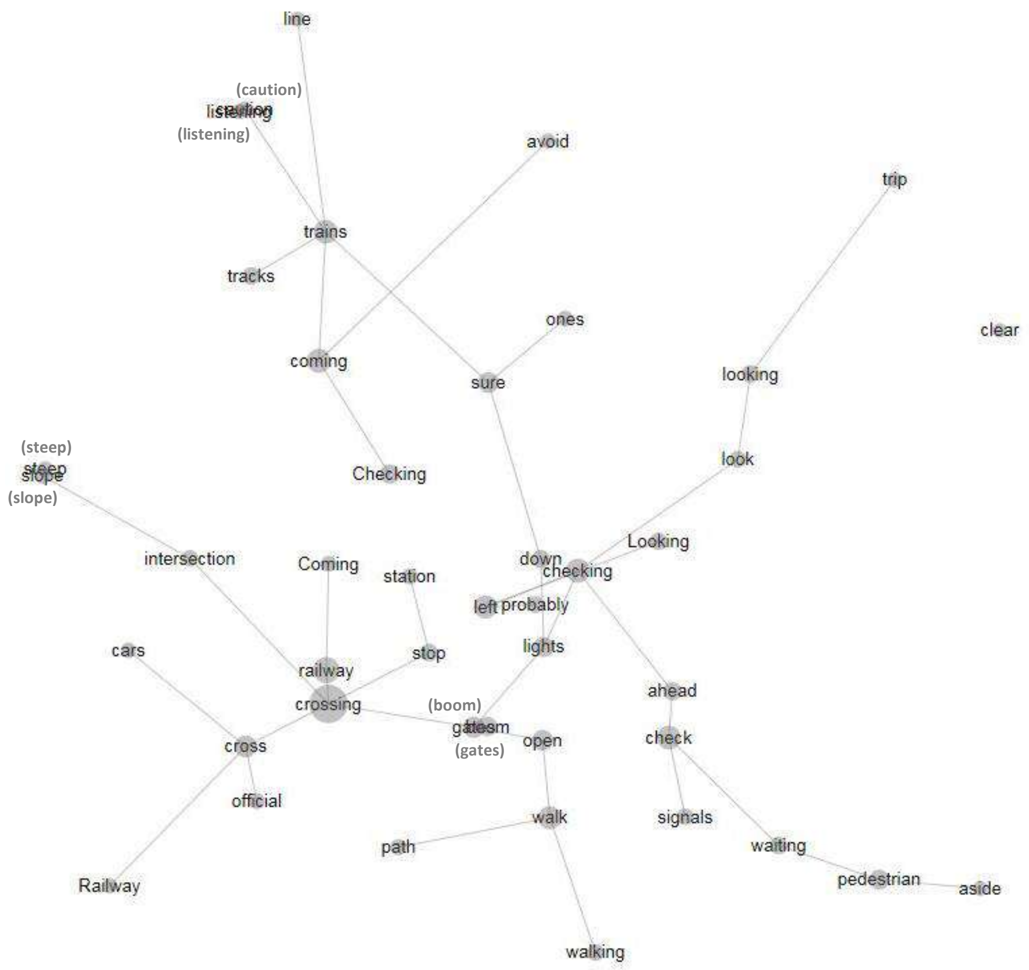

Figure 3. Concept map of pedestrian situation awareness in no train coming situations (text in brackets provided for clarification)

Manual analysis

The results of the manual coding for the key concepts is presented in Table 1 in order of the frequency of the concepts across the verbalisations provided by participants in both *train coming* and *no train coming* conditions. Key concepts were defined as those where there were five or more instances across the total sample. The low percentages show the level of variation present in the concepts identified from the verbal protocols.

Table 1 shows that regardless of whether a train is approaching, participants most often mentioned the train. Secondly, participants mentioned the presence of other pedestrians fairly equally across the conditions. There appears to be some important differences, however, between the verbalisations provided by participants across conditions. For example, for the *no train coming* situation, the concept of 'railway crossing' made up 7.1% of the concepts mentioned, yet it only made up 2.2% of the concepts for the *train coming* condition. Further, participants who did not encounter a train were more likely to mention being 'sure', the 'path', whether it was 'clear' and the 'pedestrian gates'. This is particularly interesting given that the gates are only salient when they close in front of the pedestrian, yet no participant who encountered a train mentioned them.

Overall, the participants appeared to be more concerned with the presence of a train than with the warning signals at the RLX (e.g. boom gates, lights and pedestrian gates). The bells do not appear in Table 1 as they were only present in the verbal protocols four times (all during *train coming* encounters), and as such were not considered to be a key concept.

In relation to participants' verbalisation of their own actions (shown in the second part of Table 1), the most frequent concept overall was 'crossing'. As might be expected, those participants not encountering a train mentioned 'checking' more frequently than those encountering a train. Although there were references to checking made by those in *train coming* situations, this occurred where the train had passed and the participant had mentioned checking for trains as they traversed the RLX. Those in the *train coming* situation were more likely to mentioned 'waiting' although, interestingly, the concept of 'stopping' was mentioned relatively equally across both situations. This reflects that a number of participants stopped at the entry to the RLX and checked for trains, even though the warnings were not activated and gates were open. Overall, the actions describe what might be considered desirable behaviours for pedestrians to engage in when encountering an RLX. For example, checking, looking, stopping, watching and avoiding could all be interpreted as cautious behaviours. There was no mention of hurrying, rushing or trying to beat a train.

Table 1. Concepts from the verbal protocols relating to information in the environment

Concept	Train coming (316 concepts)	No train coming (267 concepts)	Total (583 concepts)
Information in the environment			
Train	7% (N = 22)	7.5% (N = 20)	7.2% (N = 42)
(Other) pedestrian	4.7% (N = 15)	4.5% (N = 12)	4.6% (N = 27)
Railway crossing	2.2% (N = 7)	7.1% (N = 19)	4.5% (N = 26)
Railway tracks	2.8% (N = 9)	5.6% (N = 15)	4.1% (N = 24)
Coming	3.2% (N = 10)	3% (N = 8)	3.1% (N = 18)
Left	1.9% (N = 6)	3.7% (N = 10)	2.7% (N = 16)
Right	1.6% (N = 5)	2.6% (N = 7)	2.1% (N = 12)
Sure	0% (N = 0)	3.7% (N = 10)	1.7% (N = 10)
Path	0% (N = 0)	3.4% (N = 9)	1.5% (N = 9)
Clear	0.3% (N = 1)	2.6% (N = 7)	1.4% (N = 8)
Open	0.9% (N = 3)	1.9% (N = 5)	1.4% (N = 8)
Boom gates	1.3% (N = 4)	1.1% (N = 3)	1.2% (N = 7)
Lights	0.6% (N = 2)	1.9% (N = 5)	1.2% (N = 7)
Road	1.6% (N = 5)	0.7% (N = 2)	1.2% (N = 7)
Signals	1.6% (N = 5)	0.7% (N = 2)	1.2% (N = 7)
Activated	0.6% (N = 2)	1.5% (N = 4)	1% (N = 6)
Car	0.9% (N = 3)	1.1% (N = 3)	1% (N = 6)
Pedestrian gates	0% (N = 0)	1.9% (N = 5)	0.9% (N = 5)
Direction	0.6% (N = 2)	1.1% (N = 3)	0.9% (N = 5)
Own actions			
Crossing	6.6% (N = 21)	7.1% (N = 19)	6.9% (N = 40)
Checking	2.2% (N = 7)	8.6% (N = 23)	5.1% (N = 30)
Waiting	4.7% (N = 15)	1.1% (N = 3)	3.1% (N = 18)
Looking	2.2% (N = 7)	3.7% (N = 10)	2.9% (N = 17)
Walking	2.2% (N = 7)	2.2% (N = 6)	2.2% (N = 13)
Moving over	0% (N = 0)	3.7% (N = 10)	1.7% (N = 10)
Stopping	1.6% (N = 5)	1.9% (N = 5)	1.7% (N = 10)
Watching	1.3% (N = 4)	1.5% (N = 4)	1.4% (N = 8)
Avoiding	0.6% (N = 2)	1.9% (N = 5)	1% (N = 6)

Discussion

The aim of this paper was to explore pedestrian situation awareness at RLXs to identify findings that could be applied to improve pedestrian safety. The findings have provided a number of insights into pedestrian situation awareness and decision making at RLXs. Firstly, participants mentioned the road warnings (e.g. boom barriers / flashing lights) more often than the bells and pedestrian gates. Potentially these visual warnings are more salient in the environment. Further, if the majority of participants can be assumed to be drivers, they may be habituated to look at the road warnings rather than focussing on the pedestrian warnings. While in the situation where the pedestrian RLX footpath is adjacent to the road this strategy is suitable, there may be negative implications for the fewer number of crossings where there is no adjacent roadway and thus just a pedestrian gate and bells, or no gate at all. If individuals have a schema which directs them to search for flashing lights, the absence of lights at stand-alone pedestrian RLXs may lead them to fail to search for trains.

Secondly, it was interesting to note that the bells were mentioned by participants only four times (all during *train coming* encounters). This is in contrast to what might be expected based on the finding of Beanland and colleagues (2013) that auditory information was the most important information used by pedestrians in their decision making. Potentially, this discrepancy relates to the different study designs employed. In the survey study, participants responded to closed-ended questions which prompted them with a list of cues and information that might have influenced their decision making. In the current study, no prompts were given. The audio recordings clearly indicated that the bells were operational on all *train coming* encounters and it is unlikely that participants were not aware of their onset as all took appropriate action to stop at the RLX prior to the gates closing. Potentially, participants in this study were less likely to mention the bells specifically because they were focused on describing visual cues and information and how these were being used for decision making, rather than auditory information which may potentially be less straightforward to verbalise. If pedestrians process the information about the bells in a skill-based or automatic manner, this may be difficult for them to verbalise.

Additionally, many concepts were associated with other pedestrians and the need to move for, or avoid them. This was present in both *train coming* and *no train coming* situations. There are various potential explanations for this. Pedestrians need to negotiate the space on the path with other pedestrians when they are present and this is potentially a more difficult task when many have stopped to wait at the automatic gate and then all enter the RLX at the same time once the gates open. On the other hand, the prominence of pedestrians in the data could be indicative of a propensity for pedestrians to follow other pedestrians and base their behaviour on that of others at the crossing. This requires further investigation as this following behaviour could heighten the risk of a collision when those being followed choose to violate. In some cases the presence of other pedestrians may be distracting. For example, one participant in the study made multiple remarks regarding another pedestrian who was crossing with a dog. The participant was focussed on the dog as they were concerned about its behaviour being unpredictable. Congestion may also be an issue, especially in busy urban environments. Consideration could be given to increasing the width of the pedestrian paths across RLXs (where practicable) or providing better guidance to reinforce social crossing conventions (i.e. providing arrows on the path indicating to keep to the left).

Finally, it is promising that the concept of ‘train’ was shown to have prominence in pedestrians’ situation awareness networks when encountering RLXs. This aligns with the previous finding that the train was the most important factor influencing pedestrian decision making at RLXs (Beanland, Lenné, Salmon & Stanton, 2013). The train is the hazard in this situation and should be the most important consideration. Interestingly, the fact that the train was mentioned more frequently than the risk controls at RLXs (e.g. bells, pedestrian gates, lights and boom barriers) could be interpreted as meaning that less importance is placed on the warnings than on the position of the train itself.

This can be contrasted with previous findings regarding driver situation awareness which have found that there is a focus on the flashing lights and booms (Beanland, Lenné, Salmon & Stanton, 2013) rather than the train. This may be due to pedestrians being physically closer to the tracks with time to slow and check for trains which is more difficult for drivers to achieve due to their speed and the expectation of continued traffic flow when the RLX warnings are not activated. Given that concepts associated with checking, looking, stopping and watching were prominent in the verbal protocols it could be suggested that in contrast to drivers, pedestrians may not simply rely upon the automatic warnings, but use their own judgement to make a decision about when it is safe to cross a RLX. The focus on checking may also be explained by the fact that the RLX warnings operate only when a train is coming and it is unsafe to cross, but provides no information indicating when it is safe to cross. Pedestrians are used to receiving this information at road intersections (i.e. the ‘green man’). Potentially, implementing a similar approach at RLXs would reduce pedestrian workload. However, this may not be desirable as it could also reduce the cautious behaviours identified in this study. Such potential design changes would require further evaluation and testing.

There are some limitations of the study that should be acknowledged. Firstly, this exploratory study utilised a relatively small sample. Further research should use a larger sample to ensure the full range of crossing behaviour is captured and to enable inferential statistics to be applied. Secondly, as a semi-naturalistic study, the study conditions may not be representative of those that are associated with RLX crashes. This was partly intentional to avoid placing participants at increased risk by introducing time pressures or other factors that are associated with collisions. Further research should consider how to capture naturalistic data on pedestrian situation awareness which can capture situational pressures, such as the need to catch a train. Thirdly and finally, our participants may not be representative of pedestrians who are involved in RLX collisions in urban environments in Australia. Unfortunately, there is no published data on the demographics of pedestrians involved in collisions at Australian RLXs. While it has been suggested that adult males are more likely to be involved in RLX collisions (e.g. Edquist, Hughes & Rudin-Brown, 2011; Freeman, Rakotonirainy, Stefanova & McMaster, 2013; Silla & Luoma, 2012), there are suggestions that school children and people with disabilities are disproportionately represented in fatality databases (Freeman, Rakotonirainy, Stefanova & McMaster, 2013). However, such groups were not observed to be more likely to engage in non-compliant behaviours at RLXs. The present study included adult male participants but did not seek to compare their situation awareness with other participants. Future research with a larger sample size could seek to determine if there are any differences in the cues and information used by this group to make decisions at RLXs. In addition, the improved data collection and analysis systems for pedestrian collisions at RLXs is necessary.

Related to the above, participants may not have behaved as they would usually due to social desirability effects related to their behaviour being recorded. Attempts were made to minimise this through not informing pedestrians of the true focus of the study (i.e. the RLX encounter) and having the participants initiate the walk away from the RLX to enable them to become accustomed to the recording prior to reaching the RLX. Social desirability could be addressed in future research through means such as the use of eye tracking.

Overall, these findings add to a growing body of literature around pedestrian situation awareness and decision making at RLXs. Further research is needed in this area of public safety concern to provide additional insights and recommendations to improve RLX safety.

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Predictors of older drivers' looking behaviour when negotiating intersections

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Abstract

The Driving Observation Schedule (eDOS) was developed for use in the Candrive/Ozcandrive five-year prospective study of older drivers to observe their driving behaviour. The aim of this study was to describe whether participants' looking behaviour when turning at intersections during the eDOS driving task was related to factors such as age, cognitive ability and complexity of the driving environment. One hundred and fifty-five Ozcandrive participants (Male: 71.4%; Age: M = 80.86 years, SD = 3.60 years) completed a cognitive and functional ability assessment from the Year 2 Candrive/Ozcandrive protocol, as well as the eDOS driving task that commenced from the participant's home and was conducted in their own vehicle on roads familiar to and chosen by them. Observations of participants' looking and driving behaviours during the eDOS driving task were captured from two cameras that were installed in participants' vehicle, which provided images of the driver and the forward road scene. For each turn at a four-way or T-intersection (n=981), participants' looking behaviour was coded as appropriate (e.g. left, right, ahead) or inappropriate using video recordings that were retrospectively reviewed by an observer. Other variables related to the complexity of driving environment were also coded. At 58 percent of the intersections, participants showed appropriate looking behaviour. Generalized estimating equations revealed that looking behaviour was significantly more appropriate at non-signalised intersections, when traffic volume was low and marginally significant more appropriate when turning right.

Objective

In response to perceived age-related functional impairments, many older drivers employ self-regulatory strategies to keep themselves safe while driving (Ball et al., 1998; Hakamies-Blomqvist, 1994; Koppel et al., In press). However, when turning at intersections options to self-regulate are limited. One possibility to self-regulate when negotiating an intersection is to look appropriately and double-check the driving environment (Kostyniuk & Shope, 2003).The aim of this study was to explore older drivers' looking behaviour when turning at four-way or T-intersections during the Driving Observation Schedule (eDOS) driving task. Factors predicting appropriate looking behaviour when turning, such as age, gender, cognitive ability, functional ability, or the driving environment (e.g., complexity, weather etc.), were investigated.

Methods

The eDOS driving task was developed for use in the Candrive/Ozcandrive prospective study of older drivers to observe their driving behaviour (Koppel et al., In press). The Candrive/Ozcandrive study is a longitudinal, multi-center international research program with the core objective of identifying solutions to promote older drivers' safe mobility (Marshall et al., 2013). The study involves 928 drivers aged 70 years and older in Canada and 302 drivers aged 75 years and older in Australia and New Zealand (Australia: n = 257; New Zealand: n = 45), who were recruited via media attention (newspaper, radio, television). Using a longitudinal study design, the project is tracking this cohort of older drivers for up to six years, assessing changes in their functional abilities, driving practices (e.g. exposure and patterns), as well as crashes and citations.

The eDOS driving task was conducted as part of the Year 2 Candrive/Ozcandrive protocol. It commenced from the participant's home, was conducted in their own vehicle on roads familiar to and chosen by them and lasted about 20 minutes. Participants' looking and driving behaviours during the eDOS driving task were captured from two cameras that were installed in the participants' vehicle at the commencement of the eDOS driving task, which provided images of the driver and the forward road scene. For each turn at a four-way or T-intersection, participants' looking behaviour was coded as appropriate or inappropriate. For T-intersections, looking behaviour was defined as appropriate if the participant looked at least one time to the left and one time to the right; at four-way intersections, looking behaviour was defined as appropriate if the participant looked at least one time to the left, one look to the right and one look straight ahead. Other variables related to the driving environment, like type of intersection (signalised or not signalised), traffic volume (no, low, moderate-high) or weather (clear, cloudy, rainy) were also coded. Additionally, participants underwent comprehensive evaluations as part of the Year 2 Candrive/Ozcandrive annual assessment including a cognitive assessment (Montreal Cognitive Assessment (Nasreddine et al., 2005)) and measurements of functional abilities, including the Snellen test for visual acuity (Currie, Bhan, & Pepper, 2000) and the Marottoli method for measuring neck rotation (Marottoli et al., 1998).

Results

All Ozcandrive participants were approached to participate in the eDOS driving task, however, due to technical difficulties, only 227 participants (Male: 70%; Age: M = 81.53 years, SD = 3.37 years) completed the task. The video data of 155 participants (Male: 71.4%; Age: M = 80.86 years, SD = 3.60 years) who crossed 981 intersections were analysed retrospectively by a trained observer. Due to deficiencies of one or both cameras or low video quality, the eDOS video data of 72 participants (32%) could not be analysed.

Participants turned at 408 (32%) signalised and 573 (58%) non-signalised intersections. At 529 (54%) intersections a right turn was completed and at 452 (46%) a left turn was completed. Appropriate looking behaviour was shown at 571 intersections (58%). Table 1 presents an overview of the proportion of appropriate and inappropriate looking behaviour for different turning directions and different types of intersection.

Table 1. Overview of percentage and number of appropriate and inappropriate looking behaviour when turning left or right at signalised or non-signalised intersections.

	Signalised intersections		**Non-signalised intersections**		**Total**
	Left turn % (N)	**Right turn % (N)**	**Left turn % (N)**	**Right turn % (N)**	**% (N)**
Appropriate looking	3 (26)	2 (22)	26 (256)	27 (267)	58 (571)
Inappropriate looking	128 (128)	24 (232)	4 (42)	1 (8)	42 (410)
Total	16 (154)	26 (254)	30 (298)	28 (275)	100 (981)

A Logistic Generalised Estimating Equations Model was conducted to investigate the factors that predict older drivers' appropriate looking behaviour when turning at intersections during the eDOS driving task. This model revealed two significant (type of intersection and traffic volume) and one marginally significant (turn direction) predictors of the appropriateness of older drivers' looking behaviour. The strongest predictor was the type of intersection: At non-signalised intersections, older drivers were 72.68 times more likely to look appropriately compared to at signalised intersections ($p < .001$). When the traffic volume was moderate to high, older drivers were 53 percent less likely to look appropriately compared to when there was no traffic volume ($p = .025$). There was no significant difference in the appropriateness of looking behaviour when comparing low traffic volume with no traffic volume ($p = .769$). When turning right, older drivers tended to be 1.52 times more likely to look appropriately compared to when turning left ($p = .057$). Factors such as age, gender, cognitive ability, functional abilities (e.g., neck rotation, visual acuity), and weather did not influence the appropriateness of looking behaviour significantly.

Discussion

The aim of this study was to explore older drivers' looking behaviour and to investigate factors which predict appropriate looking behaviour of older drivers when turning at an intersection. The type of intersection was significantly related to participants' appropriate looking behaviour. Interestingly, participants were significantly less likely to look appropriately at signalised intersections compared to non-signalised intersections. One potential reason for this finding is that older drivers may perceive turns at signalised intersections as low risk maneuvers and therefore just start driving without looking appropriately in each direction. However, crash data reveals a high number of crashes that occur at signalised intersections (Chen, Cao, & Logan, 2012), with unexpected red-light runners posing a high crash risk. Indeed, according to an estimation by Victoria Police (2009), 20 percent of all casualty crashes at large signalised intersections in Melbourne are due to red light running, highlighting the need for drivers to check the driving environment and not to trust in the traffic light unconditionally.

Traffic volume was another significant predictor of appropriate looking behaviour: When turning at an intersection with moderate to high traffic volume – especially on the intersection leg the driver wants to turn on to, older drivers were less likely to look appropriately compared to when turning on to a road without any traffic. One potential reason for this finding is that with the increased waiting time associated with higher traffic volume, drivers may become impatient and the acceptable gap size decreases (Hamed, Easa, & Batayneh, 1997; Polus, Lazar, & Livneh, 2003). With that, time to look appropriately decreases and cognitive workload increases (Hakamies-Blomqvist, 1994). Research shows that older driver crashes are more likely to occur during complex driving maneuvers where the cognitive demands exceed their cognitive abilities, leading to cognitive overload and leading them to make errors in the driving task (e.g., choosing an unsafe gap size) (Eberhard, 2007). In addition, older drivers were marginally more likely to look appropriately when turning right, the more complex condition, compared to when turning left. One explanation for this finding is that older drivers may be aware of the risk of right turns (i.e., having to make a safe gap selection etc.) and compensate by checking the driving environment more thoroughly. Indeed, previous research suggests that many older drivers avoid making right-turns while driving because of the perceived complexity (Ball et al., 1998; Charlton et al., 2006).

Older drivers' looking behaviour was not significantly predicted by age, gender, cognitive and functional abilities or weather. Contrary to previous research which has reported that lower cognitive and functional abilities are associated with reduced driving performance (Devlin, McGillivray, Charlton, Lowndes, & Etienne, 2012; Wadley et al., 2009) and higher crash risk (Owsley et al., 1998), there were no significant relationships between these factors and appropriate looking behaviour revealed in this study.

Limitations

Some limitations of the study are noted. First, head movements were coded as a proxy for looking behaviour. The coding depended on the subjective judgement of the trained observer and very minor head movements may not have been counted. Similarly, no statement can be made about eye movements (saccades and fixations) or attentional processes. These factors should be explored in further research. Second, the analyses are based on videos from an on-road driving task from the Ozcandrive cohort study with a convenience sample of independent, healthy older drivers who made a commitment to participate in a longitudinal study, and therefore the results may not be generalisable to all older drivers.

Conclusion

Not all older drivers looked appropriately while turning at a T- or four-way intersection. Appropriate looking behaviour was predicted by the type of intersection, traffic volume and turning direction. Taken together, these findings suggest that the awareness of risks at signalised intersections and the need to check the environment while negotiating an intersection should be raised. Additionally, the study revealed that not personal variables but road environmental ones affect older drivers' looking behaviour at intersections.

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Road policing - Telling It and Selling It – old media versus new media

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Abstract

Road policing and the media is an odd relationship at best. For the subject matter to be covered misfortune generally has to occur. Then there is the matter of what stage to tell the story from - New Media? Old Media? Some combination of the two?

As more newsrooms in metropolitan areas close and/or merge and country newsrooms disappear altogether – the question for road policing professionals is - Are we heading towards a media environment where the enforcement story is told only on the social media stage?

During the NSW Police Force Christmas road policing campaign of 1996/1997 more than 60 media interviews were conducted on radio and television.

During the 2015 Easter road policing campaign, a keynote post on the NSW Police Force and Traffic and Highway Patrol Command Facebook page received a combined reach of 143,200 and an engagement rate of 15%.

Just as the early edition newspapers and 6am radio news bulletins used to set the tone for the media cycle of the day – as road policing professionals we must ask ourselves: do we and how should we use social media to prompt mainstream media into telling our story?

Who is in the audience?

As at 2 July 2015 the Traffic and Highway Patrol Command (THWPC) had 173,000 followers on Facebook. The NSW Police Force (NSWPF) Facebook page had 488,000 followers. The NSW Police Force Twitter account had 90,400 followers,

Compare this against the ratings for main weekday television Sydney news bulletin which ranged from 157,000 to 286,000 viewers (Source MediaSpy.org – June 11 2015).

The demographic of the NSW Police Force Facebook page was a largely female audience (61%). Of those female fans 31% are aged between 18-34 years. The largest demographic for male followers is 18-24 year-olds who make up 12% of the NSWPF Facebook audience.

Of the THWP page's 169,000 fans - 54% are male and 45% are female. Of the female fans – 21% are aged between 25-44 years. Of the male fans 31% are aged between 18-34 years, while 10% are aged between 35-44 years.

The NSW Police Force has more than 80 Facebook pages, including an Eyewatch page covering local areas.

The NSW Police Force Facebook page provides crime information, warnings and crime prevention tips that are of major or state wide significance.

At the local community level the NSW Police Fore has the Eyewatch program which has established a Facebook page in every Local Area Command (LAC) and specialist command.

Eyewatch is all about connecting the local community with local police and has been an outstanding success to date with more than 500,000 people connected to their local police or specialist commands of interest to them via Facebook.

Eyewatch is now providing the community with an alternative to attending meetings in the local hall. Community members can participate in crime prevention meetings online subject to your Neighbourhood Watch participation.

Telling their stories so they also tell ours

Within the social media sphere there is an appetite for smaller, more strategic pieces as demonstrated by responses to enforcement campaigns for railway level crossings and also more basic messaging on the locations of Driver Reviver Stations during holiday weekend.

Social media was used to highlight a Transport for NSW and NSW Police display at the 2014 Henty Field Days. The display comprised the “Pearly Gates” as featured in the Don’t Rush to the Other Side campaign and the wreckage of a car that had been involved in a crash with a train at a level crossing. The car was donated by the driver who escaped unharmed.

The image was posted to the NSWPF and THWPC Facebook pages on 24 September 2014 along with brief description of display.

Table 1: Analysis of Facebook Post on Henty Field Days 2014

	Likes	Shares	Comments	Total Post Reach	Engagement Rate
NSWPF	326	2	11	117,400	15%
THWPC	304	66	29	158,464	18%

The post allowed followers to share their stories ranging from those who have had near hits -

“I didn't realise you did this that is great I came from the country and had a couple of near misses. Very scary. And we lost some of our young friends on rail crossings. Keep up the good work and everyone please be aware of the danger”

-to those who simply wanted to show their support or offer suggestions on how to improve on the next display.

”Never play stupid games with trains. They take too long to stop and it's not just your life you affect. Don't be selfish

“Great example of sharing what happens... Luckily the girl walked away.”

A simple platform of an image allowed for people, regardless of the reason, to share their stories around a particular topic. This facilitated peer based road safety and road policing education to occur in a diverse audience without having to compete with other stories in the mainstream news cycle at the time.

The display did receive limited local mainstream media coverage as it was part of the larger Henty Field Days event.

It’s no yawning matter

The issue of tired driving recently regained social and mainstream media attention through the "Don't Trust Your Tired Self" campaign. While Driver Reviver sites were mentioned in mainstream radio interviews undertaken by senior Highway Patrol spokesperson – the question still lingered. Did the public still care about the Driver Reviver stations that had been a part of the Australian driving culture for at least a generation?

Driving while tired remains one of the biggest contributing factors in road crashes that kill or injure people. The Centre for Road safety reports that fatigue was identified as a factor in 18% of fatal crashes that occurred in 2013. http://roadsafety.transport.nsw.gov.au/downloads/crashstats2013.pdf (page 33).

At the start of the NSW Police Force Christmas 2014/15 road policing campaign, a post was placed on the NSWPF Twitter account along with the THWPC Facebook page that highlighted the locations of Driver Reviver stations across New South Wales during the festive season.

Table 2: Analysis of Facebook Post on Driver Reviver

	Likes	Shares	Total Post Reach	Engagement Rate
THWPC	385	67	28,200	5%

The share rate showed that people were still using the Driver Reviver locations and turning to social media as the easiest means to access that information.

In some circles, could this post be called a failure because of its lower engagement rate? Possibly so.

However the comments on the Facebook post, where members of the public engaged in passionate debate generated by users of the Driver Reviver program who also sought to clarify misinformation regarding whether truck drivers were refused service at Driver Reviver. The debate concluded with a member of the organising committee for one Driver Reviver site refuting the allegation and declaring that all were welcome.

The posting of Driver Reviver locations to social media at key times in the road policing calendar has allowed drivers to have location information in a readily accessible way and encourage positive road user behaviour.

A perfect media merger – Operation Tortoise 2015 - #SharetoSurvive

Rob and Karin Kinny's son Nathan was critically injured in a motorcycle crash on 15 October 2013. He was kept alive on life support until the following day as recipients for his lungs, kidneys and heart valves were made ready for the surgery. Rob, a respected radio journalist, and Karin, a nurse, agreed to speak at the launch of Operation Tortoise – the NSW Police Easter 2015 road policing campaign.

While having the family of a crash victim speak at a road policing campaign launch is not a new strategy, the nexus between old and new media in telling the Kinny's story and the road policing messages accompanying it, was pivotal.

All stories in the campaign, whether they were a photo caption, daily operation wrap up or the launch release were accompanied by the #SharetoSurvive hashtag.

Following the media launch involving NSW Police Commissioner Andrew Scipione, Rob and Karin Kinny and then Centre for Road Safety General Manager Marg Prendergast – all four television networks showed prominently placed packages in the key evening news bulletin and numerous radio interviews were conducted across the state.

Table 3: Analysis of Facebook Post for Operation Tortoise 2015 launch

	Likes	Shares	Total Post Reach	Engagement Rate
NSWPF	385	67	28,200	5%

Author of the media strategy for Operation Tortoise, Sergeant Kevin Daley APM said it was important that the language of the campaign be kept real and not descend into white noise.

This was nowhere more evident than in a quote from THWP Command's Assistant Commissioner John Hartley in the Operation Tortoise wrap-up release:

"It is apparent some of the behaviour and attitude of motorists has to change. We have to call it for what it is – it's killing people"

and

"Last week the parents of a young man who died in a collision a little over 12 months ago, pleaded with everyone to not let the worst decision in your life be your last.

"Today I'm asking everyone who uses the roads, those on holidays, those going to and from work, pedestrians alike, to think about what they're doing, if not for their own sake but for the sake of their family and friends," Assistant Commissioner Hartley said"

"The other key point in the campaign was the consistent use of the #SharetoSurvive tagline in all campaign materials and sharing the posts from the THWP Command Facebook page across onto the NSWPF Facebook page.

''This meant the road policing messages and our pleas to #SharetoSurvive were being sent to a potential audience of more than half a million people which is quite something when you compare this to nightly television news ratings.

"There was also an important element of having daily, varied social media messages to keep the social media conversation moving."

Rob said:

"Agreeing to put ourselves in front of the media for the high profile Easter road safety campaign was a big decision, so while getting our message out there to the greatest number of people was important to us both, knowing it was having an impact was the biggest reward.

Through the coverage provided by mainstream media, particularly television news and current affairs, we knew it was being seen.

However, it was through watching the response on social media, particularly Facebook, that confirmed for us that people had not just heard our message but were moved sufficiently by it to respond to, 'Like' and 'Share' it."

Rob went on:

“It’s my understanding that the Police Facebook page with Nathan’s picture and our words received 776 comments, around 7,400 likes and close to 3,000 shares in the days leading up to and through Easter.

For us, the best part of the social media element of the campaign was that it gave so many people the chance to share our words and comment on them and that their comments largely reflected the share to survive message.

Indeed, reading that our words would have a positive influence on people’s driving and that many would take the time to sit down with and talk to their driving age children about the message really did make the effort worthwhile.”

The use of relevant messaging that was easily translatable between the mainstream media platforms as well as into the social media sphere was a key factor in ensuring the campaign remained in the media and public eye throughout the five day operation.

Media outlets, across traditional and online media – including specialist sites such as www.carsguide.com.au also made mention of the heightened social media campaign by NSW Police Force during this critical time on state roads.

Four people died on NSW roads this Easter 2015 long weekend compared to two people in 2014, with 189 people being injured down 17 on last year (206 injured).

It’s all fun and games until someone learns something

But what of those quirkier on road moments in road policing that were once strictly in the domain of tall tales told in the police station meal room?

Social media allows road policing practitioners to start a conversation and convey a road safety message while using humour and also highlighting the penalties attached to taking unnecessary risks on the road.

During January 2015, one of the most popular posts of the NSW Police Force Traffic and Highway Patrol Command’s Facebook page was:

20 January 2015 - On Sunday 17 January, two people were found to be driving motorised Eskies on Jersey Road, Emerton in Sydney’s west. One person was charged with special range PCA and drive unregistered vehicle and while the other person dumped it and ran from the scene. He was apprehended by police and allegedly resisted arrest. He was charged with resist arrest and received infringement notices for drive unregistered and uninsured vehicle, and drive on footpath.

Table 4: Analysis of Facebook Post on Motorised Eskies

	Likes	Shares	Total Post Reach	Comments	Engagement Rate
THWPC	3132	1162	406,000	2200	12%

Figure 1: The motorised eskies

Source: THWP Facebook

Through use of the #loadfail, NSW Police Traffic and Highway Patrol has maintained an ongoing social media campaign highlighting the dangers of unsecured loads. Some of the photos published have been contributed by passing motorists while others were contributed by Highway Patrol personnel.

Earlier this year (**21 January 2015), a** driver and two passengers fined after Parramatta Highway Patrol stopped a car on Isabella Street at North Parramatta on 20 January 2015. The driver was issued penalty notices for driver permitting part of body to be outside window, drive vehicle with unsecured load and driver not carry licence. Both passengers were issued penalty notices for having part of body outside window. The sheeting was apparently some sort of plastic roofing material. The driver is looking at $830 in fines and losing six points from their licence. The passengers are looking at fines of $311 each.

Figure 2: #Loadfail post of the roofing material being held on by hand

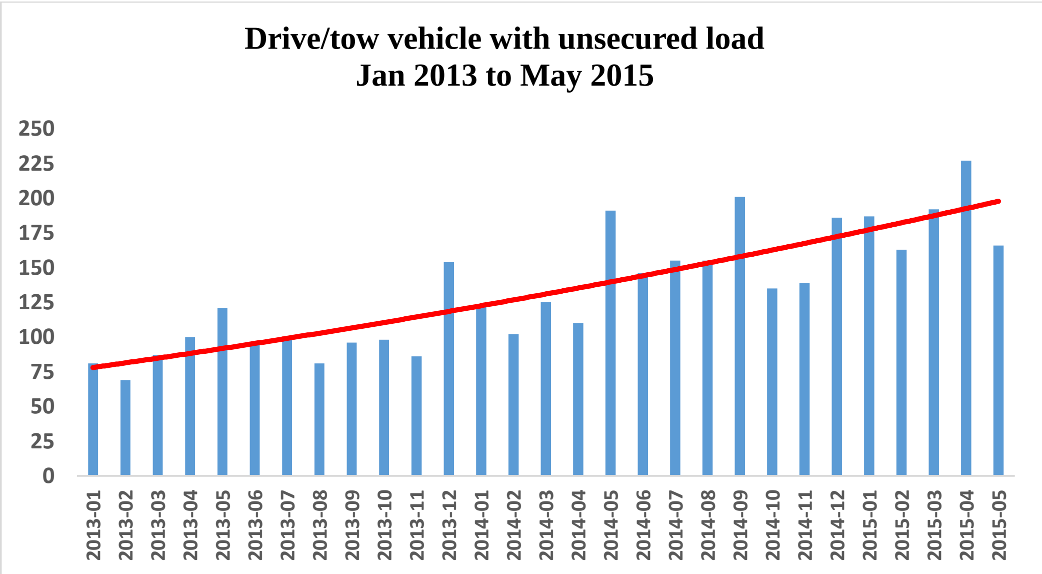
Source: THWP Facebook

Table 5: Analysis of Facebook Post on #loadfail (21 January2015)

	Likes	Shares	Total Post Reach	Comments	Engagement Rate
THWPC	1944	613	371, 456	948	17%

The #loadfail messaging has not only been embraced by the public because of its grit and realism but potentially also by NSW Police themselves. This has been shown in an upward trend in legal actions taken for the offence of "Drive/Tow Vehicle with Unsecured Load" (Australian Road Rules 2014 Clause 292).

Table 6: Unsecured Load legal actions



Provisional Police Data

Where do they get such wonderful toys?

Police and civilian use of in car video technology ranging from the formal police systems through to Go-Pro and "dash-cam" devices are becoming more frequent narrators for road safety and road policing on the social media stage.

Two items of NSW Police Force Highway Patrol in car video footage (posted in 2010 and 2011) still remain in the Top 10 most viewed clips on the official NSW Police Force YouTube channel.

The civilian use of this technology is a rapidly growing sphere with many newsroom regularly featuring dashcam footage in their bulletins. As the technology becomes cheaper, the use and prevalence of this footage can only increase. The immediacy of the incident in a real-time perspective is certainly a gamer changer for how the footage is used by media organisations.

These technologies, when coupled with social and mainstream media platforms, allow the world to see how quickly crashes can happen, what makes for acceptable on road behaviour and the need for constant vigilance when on the road.

The future is now

The future of telling the road policing story is shrouded in a little bit of mystery as the platforms and applications which will be used to do so, have probably not even been thought of yet.

The NSW Police Force has recently started using Periscope to live stream as many of its press conferences via Twitter as possible. This allows for not only greater community engagement but for media newsrooms the opportunity to source stories more readily at a time when newsrooms are shrinking in staff size but expanding in the geographical territory they cover.

By empowering commands such as the Traffic and Highway Patrol Command through the Eyewatch Program it creates a community where page followers with an interest in either the local area or the subject matter – in the case of specialist commands – can share their stories and in turn convey the core messages of the command.

Numerous journalists, producers and chiefs of staff follow the NSWPF and THWP Facebook pages creating something of an infinite loop where many stories and segments start its news life as a social media post from either a member of the public or the organisation itself.

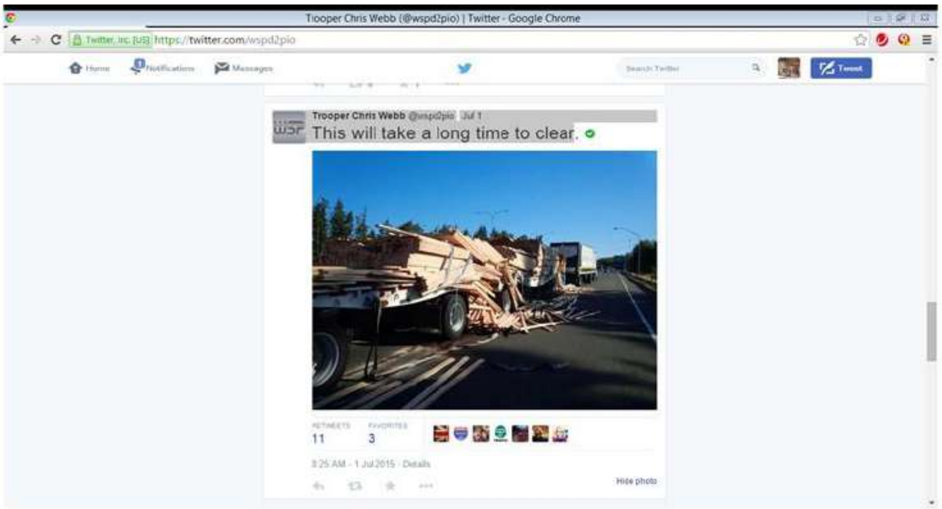
As commuter traffic grows in major cities, one of the greatest challenges facing road policing in Australia is the inevitable delays caused as a crash site is resolved and the roadway is returned.

The biggest frustration of the public through forums such as talk back radio are the reasons behind any delay.

As demonstrated by Washington State Patrol and Massachusetts State Patrol, having authorised troopers live tweet from the scene can often ease the public mood through a simple tweet and accompanying photo. This places the motorist at the crash site with emergency services and helps to manage the expectations of motorists.

This is particularly important in the case of heavy vehicle incidents where trucks and their loads can be upturned, blocking several lanes and large salvage equipment is required.

Figure 3: Incident start: Twitter feed of Trooper Chris Webb, Washington State Patrol



Screen shot taken 1 July 2015

Figure 4: End of Incident – Trooper Chris Webb, WSP

Screen shot taken 1 July 2015

Whilst news outlets and traffic helicopters do provide imagery, the relevant road authority/emergency service is denied the immediate opportunity to explain any complexities.

Conclusion

Social media has allowed the road policing story to go to where the people are – on their phone or tablet in the passenger seat of the vehicle. Through careful selection of the stories for each platform, the road policing story has never been in a better position to be told whether that is in the home, office or the passenger seat.

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Organisational Driving Safety Systems Analysis: Fleet Safety Situational Issues and System Gaps

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Abstract

The identification of safety hazards and risks and their associated control measures provides the foundation for any safety program and essentially determines the scope, content and complexity of an effective occupational health and safety management system. In the case of work-related road safety (WRRS), there is a gap within current knowledge, research and practice regarding the holistic assessment of WRRS safety systems and practice. In order to mitigate this gap, a multi-level process tool for assessing WRRS safety systems was developed from extensive consultation, practice and informed by theoretical models and frameworks. Data collection for the Organisational Driving Safety Systems Analysis (ODSSA) tool utilised a case study methodology and included multiple information sources: such as documents, archival records, interviews, direct observations, participant observations, and physical artefacts. Previous trials and application of the ODSSA has indicated that the tool is applicable to a wide range of organisational fleet environments and settings. This paper reports on the research results and effectiveness of the ODSSA tool to assess WRRS systems across a large organisation that recently underwent considerable organisational change, including amalgamation of multiple organisations. The outcomes of this project identified considerable differences in the degree by which the organisation addressed WRRS across their vehicle fleet operations and provided guidelines for improving organisations' WRRS systems. The ODSSA tool was pivotal in determining WRRS system deficiencies and provided a platform to inform mitigation and improvement strategies.

Introduction

In Australia a large proportion of motor vehicles on the road are utilised for work purposes (AFMA, 2008; Rowland, Wishart, McKenzie & Watson, 2012). Research and occupational safety statistics indicate that road crashes are the most common form of work-related fatalities; with a high proportion of work-related deaths occurring during work-related vehicle travel (Haworth, Tingvall & Kowadlo, 2000; SafeWork Australia, 2012). The Australian Work, Health and Safety Act 2011 requires employer organisations and other stakeholders to ensure a safe place to work and safe system of work in the use of all work-related vehicles. However, despite the legal obligations associated with national Work, Health and Safety legislation, many organisations lack commitment and systems to address work-related driving safety. For example, many organisations fail to develop and implement the necessary risk management frameworks and processes central to minimising work-related road safety (WRRS) risk (Rowland, Watson & Wishart, 2006; Rowland, Wishart & Davey, 2005; Rowland, Wishart, McKenzie & Watson, 2012).

Previous research has suggested that upon a serious event occurring, organisations immediately express a strong desire for future prevention of similar incidents however are unclear about where to start or are generally limited in specific knowledge and experience relating to WRRS issues and subsequent control measures (Wishart, Rowland, Freeman & Davey, 2011). Consequently, organisations tend to focus on intervention strategies targeted towards the driver and driving behaviour without investigating the systems or processes impacting upon driver behaviour and safer vehicle operation (Haworth Greig & Wishart, 2008; Rowland, Davey, Freeman, & Wishart, 2008; Rowland, Wishart, McKenzie & Watson, 2012). In contrast, evidence suggests that strategies to address the WRRS problem should be directed toward the employer organisation and its safety system, as well as driver skills, ability and behaviour

(Rowland & Wishart, 2014). This concept is similar to the safe systems approach utilised in general road safety whereby road safety improvement is holistically undertaken and not solely focussed on individual factors.

Method

The identification of safety hazards and risks and their associated control measures provides the foundation for any safety program and essentially determines the scope, content and complexity of an effective occupational health and safety management system. In the case of WRRS, there is a gap within current knowledge, research and practice regarding the holistic assessment of WRRS safety systems and practice. In order to mitigate this gap, the Organisational Driving Safety Systems Analysis (ODSSA), a multi-level process tool for assessing WRRS safety systems was developed from extensive consultation, practice and informed by theoretical models and frameworks. In addition, the development of the ODSSA further expands previous tool and process development (Rowland & Wishart, 2014). Data collection for the ODSSA tool utilised a case study methodology and included multiple information sources: such as documents, archival records, interviews, direct observations, participant observations, and physical artefacts. The multi-level process adopted a triangulation approach with the data from each stage (or part) of data collection being drawn from different sources. For example, the data collection process of the original ODSSA is divided into four major parts (see Appendix A): 1) a review of organisational WRRS records, documentation and initiatives, including an analysis of crash data, prior to any organisation site visits; 2) on site interviews with all levels of staff related to WRRS practice within the organisation; 3) observations of WRRS activities at sites/workplaces; and 4) organisational physical artefacts including site and vehicle inspections. Previous trials and application of the ODSSA has indicated that the tool is applicable to a wide range of organisational fleet environments and settings (Rowland & Wishart, 2014; Wishart, Davey, Rowland, Freeman & Banks, 2009; Wishart & Rowland, 2010; Wishart & Rowland, 2012).

This extended abstract reports on the effectiveness of the ODSSA tool to assess WRRS systems across a sizeable organisation operating a large and diverse vehicle fleet. Although the organisation stated that they wanted their organisation name and specific area of operations to remain confidential, the organisation's industry is a local government authority operating in regional Queensland, Australia.

Results

Results indicated that across the organisation there was a lack of recognition and prioritisation of the dangers and risks associated with work-related driving with the same consideration as other workplace hazards. As explained below this was evidenced by deficiencies identified in processes associated with policy documentation, employee interviews, crash reporting and recording and direct observations. Additionally, the organisation failed to adequately allocate effective ownership and accountability for WRRS operations, with many in management neglecting commitment and support for fundamental aspects of their respective WRRS system. Overall the organisation has a range of initiatives and processes occurring that aim to improve work related driving safety within the organisation. However, potentially due to issues such as amalgamation and diversity of departments across different geographical locations there is evidence indicating that many of these processes are substantially compartmentalised.

The ODSSA highlighted limited documentation related to organisational WRRS policy, procedures, processes and practice. Policy and procedures state the "rules" by which all staff are required to comply, thereby ensuring that all staff are operating under the same guidelines and conditions. For example, safe driving procedures, induction requirements, risk assessment, fatigue management, journey management, maintenance and pre-start vehicle check guidelines, licence requirements, infringement and repeat offender management were not formally addressed by the organisation. Staff interviews also highlighted a lack of WRRS awareness, formalised policy and procedures, communication, responsibility, accountability and commitment. In addition, reporting, recording and analysing data, such as crash-related data, was poorly undertaken. The major concern in this area is a lack of attention to the details in reporting and recording crashes. Observations indicated considerable inconsistency across the organisation in relation to WRRS, with operational processes, practice and training varying across departments. For instance, although certain WRRS training was developed in one department, the training was not formalised or recognised across the organisation. In addition, management commitment to WRRS also differed across the organisation. From the site and vehicle inspections there seemingly exist elements of poor attitude and behaviour towards the organisation's vehicles and their use; such as "*it's not my car I don't care*" attitude. Examples include poor condition of some vehicles and objects inside the vehicle cabin which could become a dangerous safety hazard in the event of a crash.

Conclusion

The ODSSA tool was pivotal in determining the extent of WRRS policy, procedures, processes and practice within the participating organisation. In addition, the results suggest that the ODSSA tool may be applicable to a wide range of organisational fleet environments to assess WRRS, associated safety systems and inform strategies to reduce organisational work driving risk. Encouragingly, the organisation expressed a willingness to improve its current WRRS systems albeit lacking the necessary knowledge, experience and current allocation of resources to make all the necessary changes. However, results indicated that across the organisation there was a lack of recognition and prioritisation of the dangers and risks associated with work-related driving with the same consideration as other workplace hazards. Additionally, the organisation failed to adequately allocate effective ownership and accountability for WRRS operations, with many in management neglecting commitment and support for fundamental aspects of their respective WRRS system.

A further data collection stage for the ODSSA is currently under development which involves including a process that provides a baseline indicator of the level where the organisation is in regard to safety development (see Appendix A). The psychosocial measures stage will enable the quantitative evaluation of a range of potential influences to work driving safety such as organisational culture, attitudes and motivations.

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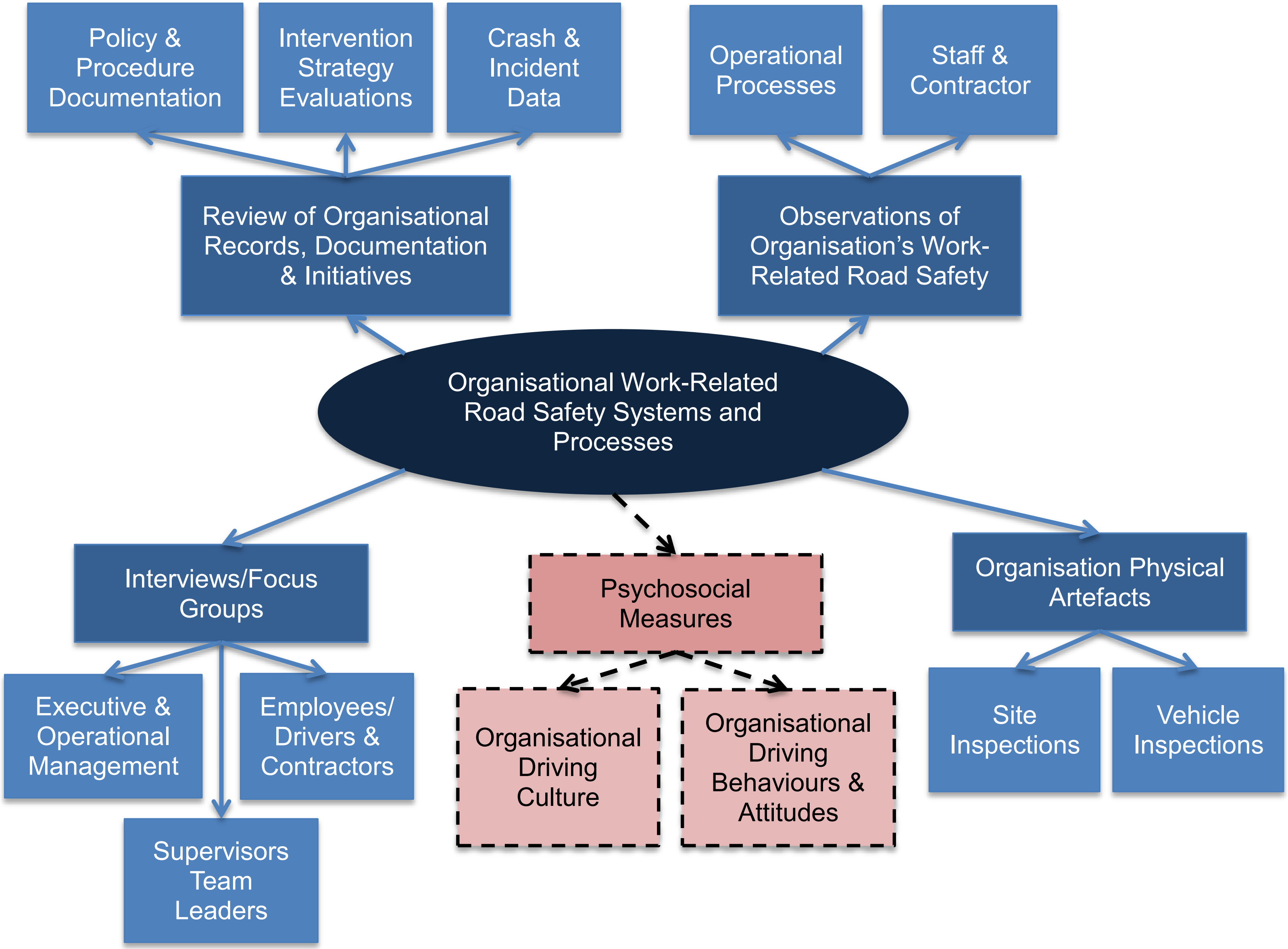
Appendix A: Organisational Driving Safety Systems Analysis



A Comparison of Road Traffic Crashes along Mountainous and Non-Mountainous Roads in Sabah, Malaysia

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Abstract

Constrained topography and complex road geometry along rural mountainous roads often represent a demanding driving situation. As a result, traffic crashes along mountainous roads are likely to have different characteristics to crashes on roads in flatter areas; however, there is little research on this topic. The objective of this study is to examine the characteristics of road traffic crashes on rural mountainous roads and to compare these with the characteristics of crashes on non-mountainous roads. This paper explores and compares general crash characteristics including crash type, crash severity, roadway geometric features and environmental factors, and road user/vehicle characteristics. Five years of road traffic crash data (2008-2012) for Sabah were obtained from the Malaysian Institute of Road Safety Research. During this period, a total of 25,439 crashes occurred along federal roads in Sabah, of which 4,875 crashes occurred in mountainous areas. Categorical data analysis techniques were used to examine the differences between mountainous and non-mountainous crashes. Results show that the odds ratio of 'out-of-control' crashes and the crash involvement due to speeding are respectively about 4.2 times and 2.8 times higher on mountainous than non-mountainous roads. Other factors and crash characteristics that increase the odds of crashes along mountainous roads compared with non-mountainous roads include horizontal curved sections compared with straight sections, single-vehicle crashes compared with multi-vehicle crashes and weekend crashes compared with weekday crashes. This paper identifies some of the basic characteristics of crashes along rural mountainous roads to aid future research on traffic safety along mountainous roads.

Introduction

Mountainous roads have complex road geometry and limited 'right of way' compared with roads in flatter areas. One of the most dominant topographical features of mountainous areas is sloped surfaces which make it challenging for designers and engineers to construct roads according to engineering standards. Combinations of vertical and horizontal alignment coupled with risky roadside environments such as cliffs and embankments make driving in these areas more demanding. Rautela and Pant (2007) reported that mountainous roads have a higher fatality index (the ratio of fatalities to road injuries) compared to roads in flatter areas, implying that crashes along mountainous roads are more severe. Lin, Jinhai, and Yan (2013) argued that crash black-spots commonly exist on mountainous roads due to their complicated road geometry and topographical conditions. Therefore, it could be hypothesised that traffic crash characteristics along mountainous roads are different from other areas; however, there is scant research on this topic.

Many factors are associated with road traffic crashes, including traffic conditions, roadway geometric features, environmental factors and driver/vehicle characteristics. Many researchers have argued that the effect of these factors on crash occurrence and injury severity vary across various locations. For instance, using a disaggregate approach Qin, Ivan, and Ravishanker (2004) demonstrated that the relationships between crashes and traffic volumes are different across different locations such as road segments and intersections. Milton, Shankar, and Mannering (2008) argued that the injury-severity outcomes are likely to be different across geographical locations. For motorcycle crashes, Haque, Chin, and Debnath (2012) demonstrated that the crash characteristics vary across location types such as intersections, expressways and other urban or suburban roads away from intersections. In a similar way, crash characteristics in urban and rural areas were compared to identify the impact of geographic differences on crash outcome, and specific interventions were suggested for rural and urban areas separately (M. D. Li, Doong, Chang, Lu, & Jeng, 2008).

In recent years, there have been some studies on road safety along mountainous roads (Ahmed, Huang, Abdel-Aty, & Guevara, 2011; Y. Chen, 2014; Yu, Abdel-Aty, & Ahmed, 2013; Zhang, Tang, & Kang, 2012; Zhou, Chen, & Xiang, 2014). Different approaches have been attempted to examine the factors influencing crash occurrence and injury severity of traffic crashes on mountainous roads. Yu et al. (2013) developed Bayesian random effect models to investigate mountainous freeway hazardous factors including geometric characteristics, weather conditions and traffic status, and found that precipitation is one of the significant determinants of traffic crashes along mountainous roads. Ahmed et al. (2011) reported that steep downgrades significantly increase crash risk along mountainous freeways, whereas the presence of wider medians reduces crash risk. Recently, Y. Chen (2014) analysed the fundamental attributes of severe crashes on mountainous highways using a cluster analysis technique and found that four key factors including long downhill sections, brake-fade, curves and poor visibility significantly influence crashes on mountainous roads. Note that brake-fade is the reduction in stopping power that can occur due to repeated or sustained application of the brakes, especially in high load or high speed conditions (Rhee, 1974). Although there is some research on mountainous road safety, much more remains to be known about how crashes along mountainous roads are different from those along roads in flatter areas.

The objective of this paper was to examine the characteristics of road traffic crashes on rural mountainous roads and to compare these with the characteristics of crashes on non-mountainous roads. The scope of this research was limited to Sabah, Malaysia, but the research findings may be applicable to mountainous areas in other geographical regions. Sabah was selected as the study area because more than 60% of its area is mountainous. It also has the steepest roads in Malaysia, which include roads with vertical gradient more than 16%.

Methodology and Data

In Malaysia, roads have been mainly divided into two groups: urban and rural roads (REAM, 2002). Urban roads are subdivided into four categories, namely expressway, arterial, collector, and local road; and roads located in rural areas are subdivided into five categories, namely expressway, highway, primary road, secondary road, and minor road. Based on the road authority definition, federal roads are those constructed and maintained by the Ministry of Works in Malaysia through funding from the federal government. Federal roads are mainly rural highways which contribute to nearly 50% of injury crashes in Sabah (MIROS, 2014). This study compares the crash characteristics along federal roads in mountainous and non-mountainous areas. Five years of road traffic crash data from 2008 to 2012 were obtained from the Malaysian Institute of Road Safety Research – Roads Accident Analysis and Database System (M-ROADS). Topographical information was obtained from the Digital Terrain Model (DTM) provided by the Department of Survey and Mapping Malaysia.

Federal roads in mountainous and non-mountainous areas were identified using the global information system (GIS) software, ArcGIS. Maps of federal roads and topographical information were overlapped to identify boundaries of federal roads in mountainous and non-mountainous areas. Following the guide on geometric design of roads in Malaysia (REAM, 2002), mountainous roads were defined as those located in areas where the natural ground cross slope is more than 25%. Following this criterion, mountainous roads represented about 208 km (14.5%) out of 1,428 km Federal roads in Sabah (IDS, 2007). After identifying mountainous and non-mountainous roads, crash data were allocated to these two types of roads by using the 'route number' variable in the M-ROADS dataset. During 2008-2012, a total of 25,439 crashes occurred along federal roads in Sabah. Among them, about 19% (4,875) crashes were identified as occurring along roads in mountainous areas and the other 81% occurred along non-mountainous roads.

This study applied disaggregate-analysis techniques to examine the differences in crash characteristics between mountainous and non-mountainous roads. Two types of outcome variable were used in the analysis: 1) crash frequency; and 2) crash percentage. A number of explanatory variables were tested by the proposed technique, including collision type, crash severity, roadway geometric features, time and day of crashes, vehicle characteristics, driver attributes and driving manoeuvres prior to the crash. A series of chi-square tests in the form of contingency tables were conducted to compare the statistical differences between mountainous and non-mountainous road crashes across the range of explanatory variables. In addition, odds ratios—which provide a relative likelihood of occurrence of events for a given category in comparison with other categories—were calculated to measure effect size and the strength of the relationship between pairs of categorical variables (McHugh, 2009).

Results

Results are discussed based on the differences in general crash characteristics, environmental factors and driver/vehicle characteristics of crashes along mountainous and non-mountainous roads.

General Crash Characteristics

Table 1 presents a univariate analysis comparing crash characteristics between mountainous and non-mountainous roads. In the M-ROADS database, there are 39 variables representing general crash characteristics of every crash such as month of crash, day of the week, road geometry, intersection type and area type. Among them, four variables were found to be statistically significant in distinguishing crashes between mountainous and non-mountainous roads. These included horizontal alignment, collision type, crash type and injury severity. As shown in Table 1, the collision type variable has eight categories including rear-end, out-of-control, head-on, angle, side swipe, vehicle-pedestrian, overturn and other crashes. While rear-end crashes were the most frequent (nearly 38%) collision type along non-mountainous roads, 'out-of-control' crashes were the most common (about 48%) collision type along mountainous roads. Compared to rear-end crashes, the odds of 'out-of-control' crashes along mountainous roads were about 4.2 times (*95%CI: 3.89 – 4.60*) higher than on non-mountainous roads. The odds of head-on, side swipe and overturn crashes were also significantly higher along mountainous roads than non-mountainous roads, with the corresponding odds respectively about 3.6 times (*95%CI 3.09 – 4.23*), 3.1 times (*95%CI 2.64 – 3.64*) and 3.4 times (*95%CI 2.84 – 4.10*) higher. Differences in the likelihood of vehicle-pedestrian collisions and angle collisions were not statistically significant across mountainous and non-mountainous roads.

Fatal and serious injury, slight injury, and property damage only crashes represented respectively about 5.8%, 2.4%, and 91.8% of crashes along mountainous roads. Similar shares of injury crashes were also observed among non-mountainous road crashes. Therefore, only the odds of a slight injury crash were statistically significantly different between mountainous and non-mountainous roads. In general, crashes along mountainous roads were slightly more severe as the fatality index (ratio of fatalities to road injuries) for mountainous roads was 0.21 whereas the fatality index for non-mountainous roads was only 0.18.

Among crash types, single-vehicle crashes were the most frequent crash type in mountainous areas, representing about 64.4% of all crashes along mountainous roads. Compared to multi-vehicle crashes, the odds of single-vehicle crashes along mountainous roads were about 2.6 times (*95%CI 2.44 – 2.78*) higher than for non-mountainous roads. Moreover, the single-vehicle crashes represented about 97% of out-of-control crashes.

The horizontal alignment of roads appeared to have more influence along mountainous roads than non-mountainous roads. Nearly 55% of crashes along mountainous roads occurred along roads with a horizontal curve, whereas only 16% of crashes in flat areas occurred along a road bend. The corresponding odds ratio suggested that the presence of horizontal curves, compared to straight road segments, increased the likelihood of crashes as much as 6.5 times (*95%CI 6.08 – 7.02*) along mountainous roads compared to non-mountainous roads.

Table 1. General crash characteristics

Variable	Mountainous, n (%)	Non-Mountainous, n (%)	OR (95% CI)	χ^2, *p*-value
Collision Type				
Rear-end*	900 (18.5)	7708 (37.5)	1.00	
Out-of-control	2317 (47.5)	4697 (22.8)	4.23 (3.89 – 4.60)	1204.893, p < 0.01
Head-on	271 (5.6)	642 (3.1)	3.62 (3.09 – 4.23)	282.901, p < 0.01
Angle and right angle side	546 (11.2)	4438 (21.6)	1.05 (0.94 – 1.18)	0.829, p = 0.36
Side swipe	248 (5.1)	686 (3.3)	3.10 (2.64 – 3.64)	206.287, p < 0.01
Vehicle-pedestrian	50 (1.0)	448 (2.2)	0.96 (0.71 – 1.29)	0.087, p = 0.77
Overturn	187 (3.8)	469 (2.3)	3.42 (2.84 – 4.10)	191.765, p < 0.01
Others	356 (7.3)	1476 (7.2)	2.07 (1.81 – 2.36)	115.017, p < 0.01
Crash Severity				
Property damage only*	4474 (91.8)	18765 (91.3)	1.00	
Slight injury	118 (2.4)	657 (3.2)	0.75 (0.62 – 0.92)	7.861, p < 0.01
Fatal & serious injury	283 (5.8)	1142 (5.6)	1.04 (0.91 – 1.19)	0.318, p = 0.573
Crash Type				
Multi-Vehicle *	1695 (34.8)	11948 (58.1)	1.00	
Single-Vehicle	3139 (64.4)	8485 (41.5)	2.61 (2.44 – 2.78)	862.435, p < 0.01
Unknown	41 (0.8)	131 (0.6)	1.18 (0.83 – 1.68)	0.863, p = 0.35
Horizontal Alignment				
Straight*	2071 (45.2)	13748 (84.4)	1.00	
Bend	2507 (54.8)	2546 (15.6)	6.54 (6.08 – 7.02)	2983.346, p < 0.01

* Reference category

Environmental factors

Table 2 presents the results of disaggregate analyses which compared environmental factors such as time of the day, day of the week and seasonal variations between mountainous and non-mountainous road traffic crashes. As reported in Table 2, night time crashes represented about 38% of mountainous crashes. Compared to day time crashes, the odds of night time crashes along mountainous roads were about 18% (*95%CI 1.10 – 1.25*) higher than on non-mountainous roads. Compared to weekdays, weekend crashes were slightly overrepresented along mountainous roads, with the corresponding odds about 10% (*95%CI 1.02 – 1.17*) higher. In terms of seasons of the year, crash occurrences between mountainous and non-mountainous roads were not significantly different across dry and wet seasons. However, in terms of school seasons, the odds of crashes along mountainous road were about 20% (*95%CI 1.12 – 1.29*) higher during school holidays.

Table 2. Characteristics of crashes by time of the day, day of the week, and seasonal variations

Variable	Mountainous, n (%)	Non-Mountainous, n (%)	OR (95% CI)	χ^2, *p*-value
Time of day				
Day time*	3037 (62.3)	13573 (66.0)	1.00	
Night time	1838 (37.7)	6991 (34.0)	1.18 (1.10 – 1.25)	28.888, p < 0.01
Day of week				
Weekdays*	3411 (70.0)	14779 (71.9)	1.00	
Weekend	1464 (30.0)	5785 (28.1)	1.10 (1.02 – 1.17)	6.975, p < 0.01
Season of year				
Dry Season*	4013 (82.3)	16873 (82.1)	1.00	
Wet Season	862 (17.7)	3691 (17.9)	0.98 (0.91 – 1.07)	0.191, p = 0.66
School seasons				
School Days*	3711 (76.1)	16305 (79.3)	1.00	
School Holidays	1164 (23.9)	4259 (20.7)	1.20 (1.12 – 1.29)	23.549, p < 0.01

* Reference category

Driver and vehicle factors

About 60% of drivers involved in crashes along mountainous roads were engaged in risky driving activities (e.g. speeding, dangerous overtaking, etc.) prior to the crash, while the corresponding percentage for non-mountainous roads was about 51%. Speeding was the most frequent risky driving behaviour among drivers involved in crashes along mountainous roads with the corresponding percentage about 32% of all mountainous road crashes. In the crash database, speeding is defined as driving over the posted speed limit. Compared to not-at-fault crashes, the odds of crash involvement due to speeding were 2.78 times (*95%CI 2.62 – 2.96*) higher along mountainous roads than non-mountainous roads. Risky driving behaviour like dangerous overtaking was also more evident among drivers involved in crashes along mountainous roads than non-mountainous roads, with the corresponding odds about 14% higher, but this estimate was only significant at 10% significance level. Other risky driving activities like ‘driving too close’ and ‘dangerous turning’ were more frequent among crash involved drivers along non-mountainous roads, with the corresponding odds respectively 25% (*OR 0.80, 95%CI 0.74 – 0.87*) and 70% (*OR 0.59, 95%CI 0.50 – 0.69*) higher than mountainous roads. Note that ‘driving too close’ and ‘dangerous turning’ are identified and recorded by the traffic police based on their evaluation of driving manoeuvers prior to a crash.

The distribution of crashes along mountainous and non-mountainous roads across vehicle types is presented in Figure 1. For both mountainous and flat areas, passenger cars represented most of the crashes. Four wheel drive (4WD) vehicles were overrepresented in crashes along mountainous roads representing about 29% of all crashes in mountainous areas. Compared to passenger cars, the odds of crash involvement for 4WDs were about 67% (*95%CI 1.57 – 1.78*) higher along mountainous roads than non-mountainous roads. Similarly, heavy vehicles were also overrepresented in crashes along mountainous roads, with the corresponding odds about 43% *(95%CI 1.32 – 1.55)* higher compared to passenger cars and non-mountainous roads. Small lorry and vans were also overrepresented in crashes along

mountainous roads, with the corresponding odds about 72% (*95%CI 1.57 – 1.89*) and 13% (*95%CI 1.00 – 1.28*) higher. In contrast, motorcycles only represented about 1.7% of crashes along mountainous roads but 5.8% of crashes along non-mountainous roads, resulting in the odds of motorcycle crashes for non-mountainous roads about 3 times higher compared to passenger cars.

Table 3 presents the distribution of crashes along mountainous and non-mountainous roads across various driver/vehicle factors. The age distributions of drivers involved in crashes along mountainous and non-mountainous roads were marginally different with young (less than 25 years old) and older drivers (more than 64 years old) being slightly overrepresented in crashes along non-mountainous roads. Female drivers were also less represented in crashes along mountainous roads, with the corresponding odds about 43% lower (*OR0.57, 95%CI 0.52 – 0.63*).

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Table 3. Driver and vehicle factors

Variable	Mountainous, n (%)	Non-Mountainous, n (%)	OR (95% CI)	χ^2, *p*-value
Driver Age				

<15	103 (1.4)	878 (2.8)	0.46 (0.37 – 0.56)	57.493, p < 0.01
15-24	771 (10.3)	3914 (12.6)	0.77 (0.71 – 0.84)	37.789, p < 0.01
25-44*	4491 (60.1)	17534 (56.6)	1.0	
45-64	1989 (26.6)	8091 (26.1)	0.96 (0.91 – 1.02)	1.860, p = 0.17
>64	113 (1.5)	586 (1.9)	0.75 (0.61 – 0.92)	7.484, p < 0.01
Driver Gender				
Male*	4258 (87.3)	16365 (63.2)	1.00	
Female	597 (12.2)	4027 (25.2)	0.57 (0.52 – 0.63)	145.532, p < 0.01
Unknown	20 (0.4)	172 (11.6)	0.45 (0.28 – 0.71)	12.193, p < 0.01
Driver Errors				
Not at fault*	3175 (40.1)	15807 (48.6)	1.0	
Speeding	2497 (31.5)	4466 (13.7)	2.78 (2.62 – 2.96)	1091.885, p < 0.01
Driving too close	892 (11.3)	5521 (17.0)	0.80 (0.74 – 0.87)	28.284, p < 0.01
Dangerous turning	188 (2.4)	1591 (4.9)	0.59 (0.50 – 0.69)	45.447, p < 0.01
Dangerous overtaking	227 (2.9)	993 (3.1)	1.14 (0.98 – 1.32)	2.890, p = 0.09
Other offences	945 (11.9)	4130 (12.7)	1.14 (1.05 – 1.23)	10.124, p = < 0.01
Types of vehicle				
Passenger car*	3534 (47.3)	16624 (53.6)	1.0	
Four Wheel Drive	2170 (29.1)	6110 (19.7)	1.67 (1.57 – 1.78)	275.539, p < 0.01
Heavy Vehicle	1032(13.8)	3391(10.9)	1.43 (1.32 – 1.55)	80.703, p < 0.01
Van	367 (4.9)	1526 (4.9)	1.13 (1.00 – 1.28)	4.093, p = 0.04
Small lorry	174(2.3)	699(2.3)	1.17 (0.99 – 1.39)	3.318, p = 0.069
Motorbike	127 (1.7)	1789 (5.8)	0.33 (0.28 – 0.40)	150.349, p < 0.01
Other vehicles	27 (0.4)	278 (0.9)	0.46 (0.31 – 0.68)	15.745, p < 0.01
Unknown	34 (0.5)	586 (1.9)	0.27 (0.19 – 0.39)	61.382, p < 0.01

*Reference category

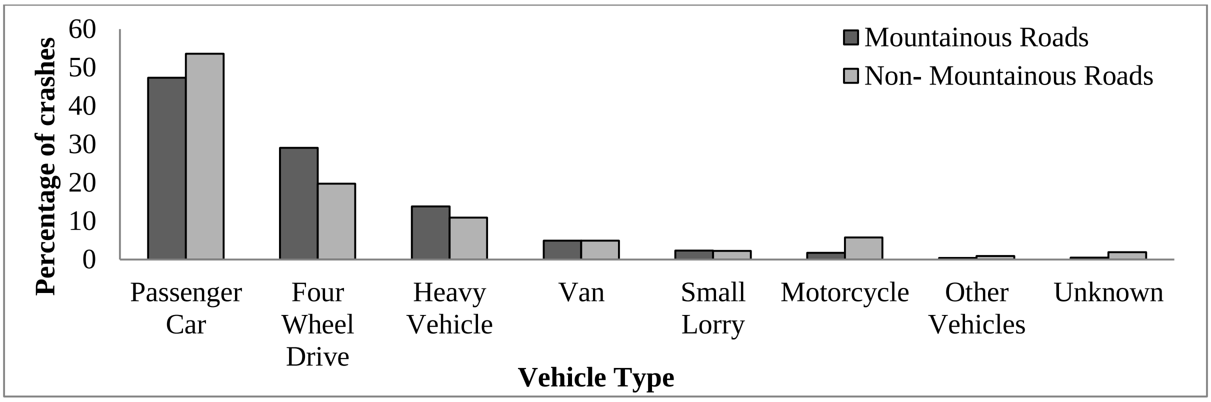

Figure 1. Percentage of crashes by vehicle type for mountainous and non-mountainous roads

Discussion and conclusion

This study examined the characteristics of crashes along mountainous roads and compared them with the characteristics of crashes along non-mountainous roads. The results have brought several new insights into the characteristics of crashes along mountainous roads which would be useful for designing countermeasures as well as targeting more focused in-depth research.

It was found that 'out-of-control' was the most frequent collision type and single-vehicle crashes were the most frequent crash type among crashes along mountainous roads compared to non-mountainous road crashes. Further, about 97% of 'out-of-control' crashes involved a single vehicle only. Mountainous roads often represent a demanding driving situation due to their constrained topography and complex road geometry. F. Chen and Chen (2013) also argued that mountainous roads with steep gradients and horizontal curves represent a unique situation and impose significant challenges to driving tasks. The second most frequent collision type along mountainous roads was rear-end crashes. While rear-end crashes may have a variety of contributing factors including roadway and traffic characteristics and driver factors, investigating their contributing factors on mountainous roads should be a worthwhile research pursuit. Other types of crashes such as vehicle-pedestrian collisions were less common along mountainous roads mainly because these roads are located in rural areas where there are fewer pedestrians. Similarly, angle or right-angle crashes were infrequent in mountainous areas because there are less intersections along rural mountainous roads.

The presence of a horizontal curve was more associated with crashes along mountainous roads than non-mountainous roads. It appears that horizontal curves represent a relatively risky situation in mountainous areas mainly because of the constrained topographical condition. In addition, a larger proportion of the road network in mountainous areas being curves represents a higher exposure along horizontal curves on mountainous roads compared to non-mountainous roads. Consistency of horizontal curves throughout the road bend is important to ensure comfortable and safe driving. Wang, Chen, Hu, and Pei (2010) reported that a road bend with a constant radius horizontal curve is safer than a road bend that consists of road curves with varying radii. M. Li, Wang, and He (2014) also reported that driving along mountainous road curves with different radii represents a dangerous situation mainly because drivers often fail to calibrate driving speed with the sudden change of road alignments. Due to constrained geometry and limitation of space, financial and technical resources, it is often challenging to construct roads following engineering standards. As a result, many horizontal curves along mountainous roads have substandard designs compared to those in flat areas, which may contribute to high crash occurrence along mountainous roads.

Night time crashes were more frequent in mountainous areas than others. Mountainous roads in Sabah generally do not have street lighting. Complex road geometries of mountainous roads in dark conditions may make the driving task even complex, and drivers may face difficulties in negotiating roads with tight curves and steep slopes. It is not clear from this research how the night time environment makes the driving task complex in mountainous areas. Future research should target investigating the influence of various road geometrical elements on night time driving behaviour and safety. Given that night time represents an unsafe environment along mountainous roads, road authorities should target provision of street lights along these roads, at least in black spot areas.

The odds of road crashes along mountainous roads were found to be higher during weekends and school holiday seasons. This may simply reflect a higher exposure of traffic along mountainous roads during times when people travel longer distances for holidays or to visit family, friends and relatives. Further research on the relationship between weekend/school holiday exposure and road crashes should be useful in this regard. Despite previous research indicating precipitation can be influential for crash occurrences along mountainous roads, the difference in crash frequencies between wet and dry seasons was not significant in this research. Seasons of a year may not contain sufficient information to compare the influence of precipitation on road safety, and hence future research should include meteorological data and compare crash frequencies between mountainous and non-mountainous roads.

Young and older drivers had lower odds of involvement in crashes in mountainous areas compared with middle aged drivers. Similarly, female drivers were less involved in road traffic crashes along mountainous roads compared with male drivers. In the cultural context of Malaysia, middle-aged male drivers often choose to drive when they travel with the family, and this may be the case when they drive in mountainous areas which impose complicated driving tasks and require long distance travel. Therefore, the high crash involvement of middle-aged males along mountainous roads may be due to their high exposure in these areas. Other than that, it is well known that males are generally more involved in crashes than females at all ages (e.g. McGwin Jr and Brown (1999)). In addition, male drivers are generally noted to partake in higher risk driving.

With respect to driver actions, speeding and dangerous overtaking were significant factors among drivers involved in crashes along mountainous roads. Lin et al. (2013) also found that speeding was the main illegal driving action in mountainous areas. As reported by Lee, Nam, and Abdel-Aty (2015), low traffic volume in rural mountainous areas may encourage drivers to increase their speed. In addition, many tourist spots are located in mountainous areas in Sabah, which attracts weekend and holiday traffic along mountainous roads there. Illegal speeding and dangerous overtaking may be initiated by drivers driving in holiday mode—this merits further investigation. Due to dangerous driving actions or manoeuvres of drivers along mountainous roads which generally have complex road geometries, many researchers have suggested strict speed enforcement along mountainous highways (e.g. F. Chen and Chen (2013)).

As per the data from the Ministry of Transportation Malaysia in 2012, more than half of vehicles registered in Sabah are passenger cars (MOT, 2012). However the odds of crash involvement for 4WDs were much higher along mountainous roads in Sabah. 4WDs, including sport utilities vehicles (SUVs), were also reported to be over involved in crashes in earlier research elsewhere (McGinnis, Davis, & Hathaway, 2001). Research from Keall, Newstead, and Watson (2006) highlighted that 4WDs are more liable to rollover crashes because of their design with a higher centre of gravity relative to the width of the wheel track. Recently, technology such as Electronic Stability Control (ESC) has been introduced to solve this problem (Chatzikomis & Spentzas, 2014), however much of the vehicle fleet in Sabah Malaysia does not yet have ESC. More research is also needed to investigate the performances of ESC along mountainous roads with tight curves and steep slopes. In addition, the exposure of 4WDs is higher along mountainous roads because people may simply prefer using a 4WD for traveling in mountainous areas. Other than 4WDs, the odds of crash involvement were also higher for small lorries and vans along mountainous roads compared with non-mountainous roads.

Heavy vehicles including rigid lorries, lorry trailers and buses represented a substantial 13.8% of crashes along mountainous roads. Their odds of crash involvements were higher along the mountainous than non-mountainous roads. Mountainous roads with steep slopes and tight curves represent an even more challenging situation to heavy vehicles due to their size and capability. Some research in the past attempted to examine the effects of heavy vehicles on mountainous road safety. For example, S. Chen, Chen, and Wu (2011) found that vertical alignments of roads and pavement surface condition influence the crash risk of trucks along mountainous roads. Yu, Xiong, and Abdel-Aty (2015) reported that the proportion of trucks in the traffic volume is negatively associated with crash rates. W. Li, Sun, and He (2010) reported that the crash risk of trucks is likely to increase with the increase in speed limits along the roads in mountainous areas. Heavy vehicles often face difficulties in maintaining driving speed both along upgrade and downgrade sections of a road with a steep slope. The slow speed of heavy vehicles often interrupts the flow of other traffic particularly along a road where no overtaking or relief lane is provided. In addition, continuous braking while travelling along a downgrade section may impose additional hazards for heavy vehicles, as continuous braking may cause brake-fade in which the braking capability of the heavy vehicle significantly reduces due to over-heating.

In Sabah, motorcycles are the second most common travel option after passenger cars (MOT, 2012). The odds of motorcycle crashes were found to be lower along mountainous roads. Motorcycles are cheaper, easy to ride and require little parking space, which makes them a good choice for middle and low income earners. However, motorcycles are less likely to be used for long distance travel and climbing up and down mountainous roads, and thus the exposure of motorcycles along mountainous roads is less.

This study has brought several new insights into the factors that influence crash occurrences along mountainous roads by analysing the crash data of the Malaysian Institute of Road Safety Research – Roads Accident Analysis and Database System (M-ROADS). To estimate and compare crash risk between mountainous and non-mountainous roads, odds ratios were calculated for a combination of various explanatory variables. Although this technique provided a good estimate of relative crash involvements, these estimates could be more reliable with exposure measures. As such, future research should focus on obtaining relevant exposure measures across various road traffic features and road users to estimate and compare the crash risk along mountainous roads as well as to identify road geometry and cross-section elements that may increase the crash risk along mountainous roads. Based on the findings of this study, potential countermeasures for mountainous roads may include lowering speed limits along high-risk road segments, providing or revising advisory speeds on curves, better delineation along horizontal curves through improved pavement markings and retro-reflective road signs, and greater use of safety barriers. However, the suitability and effectiveness of these countermeasures should be thoroughly investigated before implementation.

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Assisted Rides - A large-scale trial of a motorcycle coaching program

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Abstract

VicRide, Victoria's Assisted Rides research program, is a major case-control study intended to guide policy decision making on the benefits of training as a strategy for improving motorcyclists' safety in the early years of their riding career.

Novice motorcyclists in their learner permit and restricted licence stages are significantly over-represented in casualty crashes. Rider advocates have suggested that this is an exposure effect brought about by novice riders riding more often than their more experienced counterparts.

The Victorian Motorcycle Advisory Council, an advisory body to the Victorian Minister for Roads, had called for some time for VicRoads to undertake research into whether additional training would assist in reducing novice rider crashes. The general community has a strong view that improved rider training will deliver better road safety outcomes. This belief seems even more strongly entrenched amongst motorcyclists, perhaps because motorcycling in Australia is largely recreational and the development of high-level braking and cornering skills are seen as indicators of expertise.

Community pressure for training has also increased as Governments have sought to introduce behavioural countermeasures such as the Learner Approved Motorcycle Scheme, 0.0 BAC for riders who hold a full car licence but a restricted motorcycle licence and a Graduated Licensing System which requires more stringent testing. The argument most commonly put is that the road safety benefits achieved by these initiatives could equally be obtained with better training.

Planning for “Assisted Rides” began in 2006, when the then Minister for Roads approved funds to investigate and develop an instructor-led on-road riding course.

VicRoads identified that the key success measures for a pilot novice rider course were:

- the development of safer riding attitudes,
- reduced engagement in risk taking behaviours, and
- reduced crash involvement.

At the time, there were a number of on-road novice rider courses offered in the United Kingdom and in other Australian jurisdictions. Dr Ron Christie, who examined a number of these for VicRoads, concluded that none had been evaluated to the extent that they could be shown to meet the criteria, and nor could be immediately implemented to meet Victoria’s needs without modification.

Based on Christie’s work, the project reference group developed a list of key features that should be included in a pilot training program. This was refined through market testing to gauge the appeal a program of this type would have for motorcyclists.

A priority for the reference group was that each participant should be given as much feedback as possible, and at the earliest opportunity. This suggested that VicRoads not adopt a rigid curriculum,

but rely instead on experienced riders with high-level coaching skills to provide some common core components with a strong emphasis on personalised feedback to each participant. Another important factor was that the program should provide on-road experience in the participant's normal urban riding environment.

Having established a broad outline of the preferred model, VicRoads began developing the detail of the pilot program. In late 2008, the project forked into two distinct streams – the creation of the program content and delivery methodology, and the development of the evaluation strategy.

Curriculum Development

In 2009, VicRoads awarded a contract to the Monash University Accident Research Centre (MUARC) to undertake the development of the program content and the manner in which it was to be delivered. The early work included a literature review to identify newly licensed riders' development needs. The development needs identified in the review highlighted the importance of higher order cognitive skills, particularly hazard perception and responding, and on helping riders to recognise and manage potentially unsafe riding attitudes and behaviours.

Working with Honda Advanced Rider Training (HART) and Learning Systems Analysis (LSA), MUARC began development of an outline curriculum, to be piloted initially and then rolled out as part of the VicRide project.

Drawing on the findings of the literature review, the draft curriculum focussed on higher order cognitive skills, attitudes and behaviours. With a heavy emphasis on practical riding and personalised feedback, the curriculum set a limit of 60 minutes of classroom discussion in a 4-hour session. The role of the coach was to draw on rider's personal experiences – particularly around successful and less successful approaches to managing risk – in order to allow the riders to analyse their own beliefs. Peer discussion with the other participants allows riders to compare their experiences. Key features of the coaching program are

- a focus on self-reflective analysis of the participant's riding behaviours,
- a facilitator-led rather than didactic educative model, and
- prioritisation of behavioural reflection over skill development.

Coaching novice motorcyclists, particularly on the road, is not a simple matter. In a high-risk environment, it is easy to adopt a didactic instructional approach in order to ensure that riders are not tempted to engage in high-risk behaviour. However, the project model called for a coaching approach which relies far more on drawing on the experiences of the participants, rather than the riding expertise of the instructor. It was very clear that the ride leaders, most of whom were motorcycling instructors, would need assistance to develop their coaching skills. To address this, MUARC and its partners created an 8-day coaching course with a pass/fail assessment, which would be a pre-requisite for ride coaches. Because the coaches were expected to demonstrate safe and competent riding behaviours as well as coaching skills, the coaches' course covered topics including:

- OHS and administrative requirements,
- Roadcraft and road rules,
- Basic motorcycle handling skills,

- The differences between coaching and instructing, and when each approach is appropriate,
- The role of motivation in riding behaviour decisions,
- Effective coaching techniques, and
- Conducting coaching during the on-road ride.

The program relied heavily on role-plays to help prospective coaches to develop their listening and questioning skills, and to assist them to overcome the temptation to fall back into an instructional mode.

Coaching delivery began in 2010, and concluded in early 2014.

Evaluation

In October 2009, the George Institute for Global Health was engaged to undertake the evaluation of the VicRide pilot. Given the number of coaches available, the number of new licences issued each year and the requirement to obtain a sufficiently large sample to provide adequate statistical power, it was estimated that a sample size of around 2400 riders would be required. While a long-term crash based evaluation often provides the best measure of a safety intervention's effectiveness, the many years required to collect post-program data and the small number of trial participants meant that the evaluation would need to use proxy measures of behavioural effects.

VicRoads wrote to 15,000 recently licensed motorcyclists, and, with MUARC and The George Institute for Global Health, established an online application process to Using a monthly extract from VicRoad's licensing database, MUARC contacted potential candidates and, where the candidate consented to participate, their details were securely passed to The George Institute who, in turn, worked with Edith Cowan University's Survey Research Centre to conduct baseline interviews and then randomised the candidates into treatment and control groups. Controls were assured that, after 12 months, they would be offered the same coaching program as their treatment group counterparts.

The interview results and the group allocations were then sent back to MUARC so that they could schedule the coaching sessions. At every opportunity, the various parties were blinded as to the identity and allocation of the participants.

Risk management

Sitting alongside the evaluation and delivery strategies was a risk management program. Early on, a number of issues had been identified, most obviously, the challenges associated with taking novice riders on the road. While many of the initial concerns could be managed through existing insurance arrangements, the project identified three areas that required cover:

- Motor vehicle insurance for both third party property and comprehensive cover for riders ,
- Injury liability to cover participants whilst participating in the program but not riding on the road at the time and therefore not covered by the Transport Accident Commission insurance,
- Volunteer workers insurance to provide some cover for loss of wages for participants if they are injured.

Millers and Associates Insurance Broking Pty Limited were engaged to provide cover for each of these risks.

Challenges

Over the course of the project, a variety of challenges were encountered. These included:

- The political context of the project,
- Managing data security,
- Protecting intellectual property,
- Lower than expected recruitment and retention rates,
- Participant scheduling, and
- Dealing with challenging participants.

Addressing these has not always been straightforward. In the course of the presentation, we will explore how the issues came about, their effect on the program and how we have managed them.

See also paper titled *Development and Evaluation of an On-ride Motorcycle Coaching Program in Victoria: How well was it implemented and received by the target novice motorcycle riders?*, by Chika Sakashita, Rebecca Ivers, Teresa Senserrick, Serigne Loa, Liz De Rome, Jane Elkington and Boufous Soufiane

Development and Evaluation of an On-ride Motorcycle Coaching Program in Victoria: How well was VicRide implemented and received by the target novice motorcycle riders?

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Abstract

VicRoads initiated a large-scale trial of a newly developed 'VicRide on-road coaching program' for recently licensed motorcyclists in Victoria. The George Institute for Global Health was commissioned to evaluate VicRide primarily to determine its effectiveness in reducing crash rates for the target group via a randomised control trial. A process evaluation was also conducted to examine program delivery in parallel with the outcome evaluation. The objective of this paper is to present the process evaluation results. Data were sourced from the coaches, the program delivery organisation, and VicRide participants. Willingness to pay for VicRide was also obtained from the target novice motorcyclists. Overall the results suggest that VicRide was delivered as intended by the design on most aspects. However, the trial also identified numerous barriers to achieve high completion rates for both the preparation activity and program attendance and VicRide as a road safety intervention was valued significantly less by program participants than control riders who had not yet completed the program. Though the low completion rates may have negatively impacted the program outcomes, the barriers to completion may also reflect that individualised programs such as VicRide are practically challenging to standardise and implement as a state-wide intervention. These may be improved if all learning opportunities are contained within program attendance and the program is made mandatory. Nevertheless, these considerations are meaningful only if and when VicRide and other similar programs demonstrate detectable road safety value including crash and casualty reductions, reduced risk taking behaviours and improved safety attitudes.

Background

VicRoads commissioned Monash University Accident Research Centre (MUARC) to develop an assisted ride program for riders in Victoria in collaboration with Honda Australia Rider Training (HART) and Learning Systems Analysis (LSA). VicRoads initiated a large-scale trial of this newly developed program in Victoria for recently licensed motorcyclists. The program was named the 'VicRide on-road coaching program' (VicRide) for the purpose of the trial. The underlying principle of the VicRide teaching method was 'coaching' to influence cognitive processes of riders instead of 'instruction' to influence rider skills. The George Institute for Global Health (TGI) was commissioned to evaluate VicRide primarily to determine its effectiveness in reducing crash rates for novice motorcycle riders in Victoria (topic of another paper in this symposium). A process evaluation was also conducted to examine program implementation in parallel with the outcome evaluation.

The objective of the present paper is to present the results of the process evaluation. Its scope covered all aspects of the implementation, including the training of the VicRide coaches and the VicRide delivery. Data were sourced from the coaches, HART, and the VicRide participants. Willingness to pay value for VicRide was also obtained from the target novice motorcyclists.

VicRide on-road coaching program

The aim of the VicRide on-road coaching program was to assist newly licensed riders to become safer riders and to reduce their involvement in risk-taking behaviour and crashes. VicRide consisted of a series of short rides (15-20 minutes) on a planned route and pre- and post-ride discussions over four hours in a group of up to three newly licensed riders and an experienced riding coach. The route included both rural and urban riding environments, which were selected to expose riders to the types of situations identified as potentially hazardous for motorcyclists. Stops between ride sections were programmed to allow for discussion and review of these situations and how different riders approached them.

VicRide coaches were experienced riding instructors who volunteered for the program and undertook an intensive eight day coach training course to develop their ability to perform the role of a coach and mentor. The coaches’ training course and materials were developed as a part of VicRide by MUARC, LSA, and HART. HART independently delivered the coach training.

VicRide adopts a learner centred approach (Zepeda, Parylo et al. 2013) and insight training (Gregersen 1996, Symmons, Mulvihill et al. 2007, Rowden and Watson 2008). The focus of VicRide was on higher order riding skills including cognitive strategies for safe riding, especially in relation to road craft, hazard perception, motivations and experience. The coaching process was to encourage riders to express their opinions and give feedback to each other. The role of the coach was to facilitate these discussions, intervening only as necessary and by using questions rather than answers to re-focus discussion. At the end of the route, the coach facilitated a final group discussion for the riders to review their own learning from the day and determine what each needed to do to keep improving their safe riding skills.

On enrolling in VicRide, participants were sent an information booklet about the program and prerequisites for their participation. Prerequisites included becoming familiar with the hand signals to be used by their coach, and completion of a short survey designed to stimulate reflection on their riding experiences to date. Their responses also provided an indicator of their crash risk profile. On the day of the VicRide, participants were required to demonstrate to the coach that their motorcycle was in sound mechanical condition and that they had basic competence in braking, cornering and obstacle avoidance.

Methods

Coach training and survey

On the last day of the coach training, the coaches were asked to complete an anonymous paper-and-pen survey developed by TGI. The survey contained questions about the coach training and VicRide program using rating scales and open-ended questions. Each coach put the completed survey in an envelope and handed it to the HART trainer of the coaches. HART then sent all the completed surveys in the envelopes to TGI by mail.

VicRide delivery data recorded by HART

The aim of the VicRide delivery data collection by HART was to monitor the degree of adherence of the actual delivery to the intended program design. Data were recorded by the coaches on the key delivery components of VicRide (e.g. reason for non-completion, duration, weather, etc) for every participant specified for the evaluation. These data were sent to TGI in Excel at the end of each month.

VicRide booking and participant survey

Participants completed three surveys via telephone interviews over the course of the evaluation study. At the completion of the baseline interview, participants were randomly assigned to either the VicRide group or control group. Those assigned to the control group were advised that they could take part in VicRide at the completion of the final interview in about 12 months' time. All riders were provided with a phone number for HART and a reference number for them to use when booking with HART. Riders allocated to the VicRide group were to call and book with HART within six weeks of the baseline interview and control riders were offered to call and book with HART after completing the final interview. HART had these reference numbers from TGI to cross check that HART was booking in only VicRide riders who had completed the baseline interview (but not the two follow-up interviews) and control riders who had completed all the three interviews. HART also had from TGI the baseline interview date and contact details of the VicRide riders so that they could call the riders for booking into the program if the riders had not called after a week since the baseline interview date.

Subsequent interviews were conducted at three months (Interview-2) and 12 months (Interview-3) after the date of VicRide participation for the VicRide group and at similar timeframes after the baseline interview for the control group. At Interview-2, the VicRide group only were asked questions for the process evaluation. They were asked 16 questions about their VicRide experience with a four-point rating scale (strongly agree; agree; disagree; strongly disagree) to assess overall participant satisfaction with the program. This produced a total satisfaction scale from one to four with higher scores indicating higher satisfaction with VicRide. Open-ended questions were also used for some questions about the experiences of VicRide participation because VicRide is a new program that was trialled for the first time and it was not possible to pre-categorise possible responses.

Willingness to pay for VicRide among novice motorcyclists

At Interview-2, both VicRide and control riders were also asked about their willingness to pay (WTP) for VicRide. Although VicRide was offered for free as part of the trial the WTP was asked in a hypothetical scenario as a measure of motorcycle riders' perceived value of VicRide as a road safety intervention. The WTP amount was modelled with a simple linear regression adjusting for age, gender, and riding exposure (riding hours in an average week) reported at baseline as well as time to follow-up (i.e. days between baseline and Interview-2) to examine any differences in the values placed by the two study groups.

Results and Discussion

Process evaluation data consisted of categorical and continuous variables as well as free responses. Categorical variables were summarised by frequencies and percentages. Continuous variables were summarised using mean and standard deviation as well as minimum and maximum values. Human coding of the free responses was conducted rather than computer coding because many responses were expressed in a convoluted manner. Response category names were developed and refined following multiple steps of coding and theory-driven and data-driven coding rules based on the common themes identified in the free responses.

Coach training and survey

Of the 22 coaches who completed the coach training, 18 (82%) completed the survey after the coach training. Characteristics of these coaches are summarised in Table 1.

Table 1. VicRide Coach Characteristics

Characteristics	**Coach survey (N = 18)**
Age (years)	
Mean (SD)	44.8 (6.84)
Min Max	32.0 57.0
Gender	
Female	1 (5.6%)
Male	17 (94.4%)
Riding years	
<1 year	0 (0.0%)
1 - 5 years	0 (0.0%)
5 - 10 Years	0 (0.0%)
>10 years	18 (100.0%)
Riding frequency on public roads	
Less than once each month	0 (0.0%)
At least once a month	0 (0.0%)
At least one day a week	0 (0.0%)
2-3 days a week	4 (23.5%)
4-6 days a week	6 (35.3%)
Everyday of the week	7 (41.2%)
2 or 3 days per month	0 (0.0%)
Riding hours per week	
Mean (SD)	9.0 (5.43)
Min Max	2.0 25.0
Riding km per week	
Mean (SD)	472.9 (191.40)
Min Max	190.0 900.0
Motorcycle instructor years	
Mean (SD)	7.4 (5.55)
Min Max	0.8 23.0
Motorcycle instructor employment status	
depends on the season	0 (0.0%)
part-time	7 (38.9%)
full-time	11 (61.1%)
Working days as a motorcycle instructor in the last 12 months	
Mean (SD)	143.9 (95.43)
Median (Q1, Q3)	121.5 (50.0, 250.0)
Min Max	12.0 260.0

Coach views of the coach training and VicRide are summarised in Table 2 and Table 3 respectively. The coaches were also asked about their views of the differences between ‘instruction’ and ‘coaching’ and identified two themes: 1) Instruction is telling the students “how to” while coaches facilitate the students to find the answers themselves; 2) Instruction is focused on skills but coaching is focused on influencing the cognitive processes. These suggest coaches had grasped the underlying principle of the VicRide teaching method.

Table 2. Coach Views of Coach Training

Characteristics	Coach survey (N = 18)
VicRide coach training duration	
too short	8 (44.4%)
about the right length	8 (44.4%)
too long	2 (11.1%)
VicRide coach training delivery pace	
much too slow	0 (0.0%)
a bit too slow	1 (5.9%)
about right	13 (76.5%)
a bit too fast	3 (17.6%)
much too fast	0 (0.0%)
Coach rating of coach training out of 10 - delivery skills	
Mean (SD)	7.8 (0.83)
Min Max	6.2 8.9
Coach rating of coach training out of 10 - coaching skills	
Mean (SD)	8.3 (1.24)
Min Max	5.0 10.0

Table 3. Coach Views of VicRide

Characteristics	Coach survey (N = 18)
VicRide discussion-ride balance	
Not enough discussion and too much on-road riding	0 (0.0%)
About the right balance	17 (100.0%)
Too much discussion and not enough on-road riding	0 (0.0%)
Coach rating of VicRide out of 10	
Mean (SD)	7.6 (0.60)
Min Max	6.6 9.0

The VicRide coaches were experienced riders and trainers with an average of over 10 years of riding experience and an average of 7.4 years of being rider trainers. Most coaches believed the coach training was either too short or just right, but they generally rated the training highly with average scores of 7.8 out of 10 for delivery skills and 8.3 out of 10 for coaching skills. The coaches generally rated VicRide highly with an average score of 7.6 out of 10.

All these results suggest that the coach training was delivered adequately to equip the coaches with the required delivery and coaching skills and good understanding of the ‘coaching’ style as opposed to ‘instruction’ style of teaching.

VicRide delivery data recorded by HART

Of the 748 VicRide riders for whom HART provided delivery records, 28 of them were recorded as 'did not complete the VicRide program'. The reasons recorded by HART for not completing the program included ineligible (n=20), bad weather (n=5), and voluntary withdrawal by the rider (n=3). The program delivery adherence was assessed on the delivery records for the 720 riders who HART recorded as having completed the entire program (Table 4).

VicRide was designed to be run over four hours and delivered in a group of two to three riders. The actual program duration ranged from three to five hours with an average of four hours, and the actual group size ranged from one to three. The majority (93.2%) of the riders participated in the program in a group of two (42.2%) or three (51.0%) riders, but a small percentage (6.8%) participated on their own. Most (94.3%) of the riders participated in metropolitan locations. All VicRide riders should have received a preparation activity booklet from HART before the actual program delivery date. Only 71.1% of riders who attended the program completed the preparation activity before the actual program participation. Reasons for not completing the preparation activity were only reported for 36.1% of those who did not complete the activity. The reasons were either that the riders did not receive the preparation activity booklet (48.6% of those who provided reasons) or riders did not have enough time (51.4%).

The coaches rated the participants' overall engagement during the program on a scale from one (never) to four (always). The coaches assessed 80.6% of the rider participants to be always engaged, 17.2% most of the time, and 2.2% half the time. The coaches also rated the rider participants' level of following hand signals during the course on a scale from one (never) to four (always). The coaches assessed 78.7% of the rider participants to follow hand signals all the time, 19.9% most of the time and 1.4% some of the time. This relatively low rate of following hand signals may be likely due to almost 30% of the riders not having had received or completed the preparation activity before the program participation. All the participants completed the rides in light traffic conditions, heavy traffic conditions, and in metropolitan environments. Most of the participants (99.3%) also completed rides in rural environments but a small percentage (0.7%) did not.

VicRide booking and participant survey

A total of 1232 riders were randomised into the VicRide group. The majority (81.2%) were males and the average age was 35.3 years (SD=11.27). Of the 1232 VicRide riders, 1061 (86.1%) were successfully followed up for the second interview and 704 riders (57.1% of the original VicRide riders) reported they had completed VicRide. The 357 (29.0%) VicRide riders who were successfully followed up for the second interview but had not completed VicRide were asked in an open-ended question about the main reason for non-completion. Although the reasons varied widely, the top three reasons for not completing the program were work (23.1%), no bike (18.8%), and lack of time (17%).

Those VicRide riders who reported they completed the program (n=704) were asked a series of questions about their experience of VicRide participation. The results are summarised in Table 5. The total satisfaction score ranged from 1.94 to 4 with a mean of 3.2 (SD=.42). This mean equates to eight out of 10. Most riders believed the program duration, the speed of the on-road rides, and the balance of discussion and on-road riding were about right. When asked about what the VicRide participants liked about the program, though the views varied widely, the top three comments were 'coach quality' (20.1%), 'receiving feedback' (17.4%), and 'group discussion' (16.1%). These features are in line with the intended design of the VicRide program.

Table 4. VicRide delivery based on HART records

Characteristics	VicRide program (N = 720)
HART program duration	
Mean (SD)	4.0 (0.21)
Median (Q1, Q3)	4.0 (4.0, 4.0)
Min Max	3.0 5.0
VicRide group size	
1	49 (6.8%)
2	304 (42.2%)
3	367 (51.0%)
VicRide delivery location	
Bendigo Rural	37 (5.1%)
Warragul Rural	5 (0.7%)
Somerton Metro	292 (40.6%)
Kilsyth Metro	238 (33.1%)
Cranbourne Metro	148 (20.6%)
VicRide prep activity completed by participant	
No	205 (28.9%)
Yes	505 (71.1%)
VicRide prep activity non-completion reason	
None provided	19 (20.4%)
Book not received	36 (38.7%)
Not enough time	38 (40.9%)
VicRide hand signals followed	
Never	0 (0.0%)
Some of the time	10 (1.4%)
Most of the time	142 (19.9%)
All the time	562 (78.7%)
VicRide participant engagement	
Never	0 (0.0%)
Half the time	16 (2.2%)
Most of the time	123 (17.2%)
Always	578 (80.6%)
VicRide metro route completed	
No	0 (0.0%)
Yes	719 (100.0%)
VicRide rural route completed	
No	5 (0.7%)
Yes	714 (99.3%)
VicRide light traffic condition completed	

No	0 (0.0%)
Yes	719 (100.0%)
VicRide heavy traffic condition completed	
No	0 (0.0%)
Yes	719 (100.0%)

Table 5. VicRide participant feedback

Characteristics	**VicRide group (N = 1061)**
Program completed or not	
No	357 (33.6%)
Yes	704 (66.4%)
VicRide participant satisfaction scale score out of 4	
Mean (SD)	3.2 (0.42)
Min Max	1.9 4.0
VicRide course duration	
Too long	17 (2.4%)
About the right length	573 (81.4%)
Too short	114 (16.2%)
On-road riding speed	
Much too fast	0 (0.0%)
A bit too fast	5 (0.7%)
About right	613 (87.2%)
A bit too slow	77 (11.0%)
Much too slow	8 (1.1%)
Discussion-ride balance	
Not enough discussion and too much on-road riding	26 (3.7%)
About the right balance	620 (88.1%)
Too much discussion and not enough on-road riding	58 (8.2%)

Willingness to pay for VicRide among novice motorcyclists

All the Interview-2 respondents provided a WTP value for VicRide. The WTP ranged from 0 to 1000 with a mean of $175 (SD=137.8). The certainty of the WTP choice ranged from one to ten with an average of 8.1 (SD=2.0). The certainty level was very high across all study participants and did not differ between the two groups. Therefore all WTP values were used in subsequent analyses.

The average WTP was lower amongst the VicRide riders ($162; SD=127.3; n=1061) than the control group riders ($188; SD=146.33; n=1067). Further analyses showed that the highest WTP amount for VicRide was statistically significantly lower for the VicRide group than the control group, even after accounting for age, gender, and riding exposure (adjusted beta coefficient=-0.277; p<.0001). That is, the VicRide group valued VicRide significantly less than the control group.

Table 6. WTP for VicRide for VicRide vs Control Groups

	Univariate estimates		**Adjusted estimates**	
Variables	**coefficient (95% CI)**	**P-value**	**coefficient (95% CI)**	**P-value**
VicRide vs. Control	***-.264 (-.381, -.148)***	***<.0001***	***-.277 (-.393, -.161)***	***<.0001***

Age	0.019 (0.014, 0.024)	<.0001	0.018 (0.013, 0.023)	<.0001
Gender (Male vs. Female)	-.130 (-.278, 0.019)	0.0880	-.051 (-.200, 0.098)	0.5000
Riding exposure (hours/week)	-.031 (-.047, -.015)	0.0001	-.027 (-.042, -.011)	0.0010

These results are shown in Table 6. Changes in perceived value from pre to post intervention experience are not uncommon in relation to transport policy, such as congestion charges (Schuitema et al. 2010) and random breath testing (Job et al. 1997).

Implications

Overall the results suggest that the VicRide program was delivered as intended by the design on most aspects. However, the trial also identified numerous barriers to achieve high completion rates for both the preparation activity and program attendance and VicRide was valued significantly less as a road safety intervention by program participants than control riders who had not yet completed the program. Though the fact that almost 30% of the participants had not completed the preparation activity before the program participation may have negatively impacted the program outcomes, the barriers to completion for both the preparation activity and program attendance may also reflect that individualised programs such as VicRide are practically challenging to standardise and implement as a state-wide intervention. These may be improved if all learning opportunities are contained within program attendance and the program is made mandatory to maximise control of the delivery and ensure completion to cater for all levels of motivation. Nevertheless, these considerations are meaningful only if and when VicRide and other similar programs demonstrate detectable road safety value including crash and casualty reductions, reduced risk taking behaviours and improved safety attitudes.

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Who's in control of the fatal five? A systems analysis of Queensland's road transport system

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Abstract

Despite significant progress, road transport systems continue to kill people on a scale that is comparable to cancers, cardiovascular disease, and respiratory diseases. In Queensland (Qld), Australia, there is currently a targeted focus on reducing the 'fatal five' behaviours underpinning road trauma. Although progress is being made, researchers have argued that a new systems thinking approach is required in order to create more significant safety gains. This paper describes a study that used the STAMP systems analysis methodology to develop a control structure model of the road transport system in Qld. The control structure model depicts the actors/organisations within the Qld road transport system (e.g. road users, road designers, vehicle manufacturers, road safety authorities, research groups, government agencies, advocacy groups) along with the control relationships that exist between them. The analysis depicts a shared responsibility for the fatal five behaviours, and shows that, compared to other safety critical domains, there are less formal control structures and that opportunities exist to add new controls and strengthen existing ones. Further, current crash analysis systems are brought into question by the model. In closing the practical implications for road safety interventions are discussed.

Introduction

There is no doubt that significant progress has been made by the road safety community in its attempts to reduce road trauma. Indeed, in most areas roads are now the safest they have ever been. Despite this, the facts around current and projected levels of road trauma still make for sobering reading: in 2012 road injury was the ninth leading cause of worldwide deaths and it is estimated that it will be the fifth leading cause of deaths by 2030 (WHO, 2011; 2014).

This continuing burden is unacceptable. Recently researchers have suggested that a new systems thinking approach is required in order to achieve new reductions in trauma (e.g. Salmon and Lenne, 2015). This argument is based on the success of systems thinking approaches in other safety critical systems and on the notion that the current road safety approach does not sufficiently consider the complex sociotechnical nature of road transport systems. This is despite confirmation that road transport systems do display all of the characteristics of complex sociotechnical systems (e.g. Larsson et al, 2010; Salmon et al, 2012).

Traditionally road safety efforts have involved a focus on one component of the problem (e.g. driver behaviour) and an attempt to improve performance of that component (i.e. make drivers more compliant). This is currently exemplified in Queensland by the focus on the fatal five behaviours that create road trauma: speeding, drink and drug driving, failure to wear a seatbelt, driving while fatigued, and distraction and inattention. The prevalent approach to limiting road trauma involves attempting to prevent drivers from engaging in the fatal five behaviours through driver-centric measures such as education and enforcement.

In recent times this component approach has received criticism. For example, it has been argued that the inherent complexity in transportation systems and the multitude of factors shaping behaviour have not been fully considered (Cornelissen et al, 2015; Larsson et al, 2010; Salmon et al., 2012; Salmon and Lenne, 2015). The consequence is that many factors influencing behaviour may be left untouched, diminishing the effectiveness of road user focussed interventions such as education and enforcement (Larsson et al, 2010; Salmon et al., 2012). An absence of systems thinking in system and countermeasure design is now widely acknowledged to represent a key issue in safety critical systems (e.g. Dekker, 2011; Reason, 1997).

Accidents are known to be emergent properties of complex sociotechnical systems; that is, factors from across the overall ‘system’ interact to create them (Dekker, 2011; Leveson, 2004; Rasmussen, 1997). Road transport is a complex sociotechnical system, comprising many inter-related components (Larsson et al, 2010; Salmon et al, 2012), yet the role of factors outside of road users, vehicles and the road environment in road trauma remains unclear. Notably, there is limited information regarding the systemic factors that interact to create the fatal five behaviours. The growing complexity of road transport systems may have outpaced our understanding of what they comprise, of what factors interact to create road trauma, and of how to make them safer.

To cope with this complexity, a complex sociotechnical systems approach is required; however, despite being a proven approach to enhancing safety in other domains, this is only beginning to gain traction in road safety circles (Salmon and Lenne, 2015). As a first step in initiating a systems thinking approach to road trauma, Larsson et al (2010) and Salmon et al (2012) identified the need to use complex system modelling approaches to describe road transport systems and the interrelations between entities within them. Similarly, Salmon and Lenne (2015) argued that such approaches should be applied during road system analysis efforts. This paper is a direct response to this, presenting a Systems Theoretic Accident Model and Process method (STAMP; Leveson, 2004) control structure model of the road transport system in Qld, Australia. The aim of the exploratory study was to delineate the range of actors and organisations within the Qld road transport system along with the key relationships that exist between them.

Method

The control structure component of STAMP (Leveson, 2004) was used to construct a model of the Qld road transport system. STAMP is an accident model and analysis method that views accidents as resulting from the inadequate control of safety-related constraints (Leveson, 2004), arguing that they occur when component failures, external disturbances, and/or inappropriate interactions between systems components are not controlled (Leveson, 2004; 2011). Leveson (2004) describes various forms of control, including managerial, organisational, physical, operational and manufacturing-based controls. STAMP uses a ‘control structure’ modelling technique to describe complex systems and the control relationships that exist between components at the different levels. A taxonomy of control failures is then used to classify the control failures that played a role in the incident under analysis. An additional component of STAMP involves using systems dynamics modelling to analyse the behaviour of the system over time. This enables the interaction of control failures to be demonstrated along with their effects on performance. Whilst the method has typically been used for the analysis of large-scale catastrophes, the control structure component is useful in isolation as a systems modelling tool (Salmon et al, 2012).

Initially two researchers constructed the control structure model based on various sources, including road system documentation (e.g. road rules and regulations, road safety strategies, policy documents), stakeholder websites (e.g. Transport and Main Roads Queensland website), and the academic literature. Following this, a third analyst then reviewed the model and provided feedback. All three analysts then met and worked through the model until all were in agreement regarding its structure and components. The model is currently being validated via a Delphi study involving road safety experts, systems thinkers, and complex system modelling experts, however this has not yet been finalised and so the results are not reported here. The final validated model will be included in the conference presentation.

Results

STAMP control structure model of Qld road transport system

A generic STAMP control structure model is presented in Figure 1. The control structure model incorporates two components: the control structure for system design and development, and the control structure for system operation. In the present analysis, both control structures were developed; however, due to space constraints only the control structure for system operation is discussed.

The system operation control structure model of the Qld road transport system is presented in Figure 2.

Within Figure 2, the downward flowing arrows and text linking the higher levels to the lower levels represent control mechanisms imposed by actors and/or organisations at the level above on actors and/or organisations at the level below. For example, Police officers at level 4 of the model impose control on the road users at level 5 via monitoring, enforcement and penalties. Likewise, at level 1 national and federal parliaments impose control on the level below (government agencies, industry associations, user groups and the courts) through national policy.

As noted previously, control can be achieved in various ways including through managerial, organisational, physical, operational and manufacturing-based controls. That is, behaviour is controlled not only by engineered systems and direct intervention, but also indirectly by policies, procedures, shared values, and other aspects of the organisational culture. It is notable that there is a mixture of control types shown in the draft control structure. Finally, it is worth noting that control mechanisms might exist between non-adjacent levels (as represented by curved arrows). For example, at level 3 Transport and Main Roads Queensland imposes licensing and registration controls on road users at level 5.

The dashed arrows flowing upward through the model in Figure 2 represent feedback mechanisms whereby actors/artefacts/organisations provide information regarding the status of the system to those higher up in the system. This is a key component of system functioning and enables higher levels to understand how the system is operating at the lower levels, which in terms informs decision-making. For example, 'Government reports' are a feedback mechanism provided by Level 2 (government agencies, industry associations, user groups and the courts) to Level 1 (parliament and legislatures). At the lower levels of the system, crash reports are provided to Police officers (Level 4) by road users (Level 5) who were either involved in the crash or witnessed the crash. As with the control relationships, feedback relationships may exist between adjacent levels of the control structure (shown by straight dashed arrows) or they may exist between non-adjacent levels (shown by curved dashed arrows).

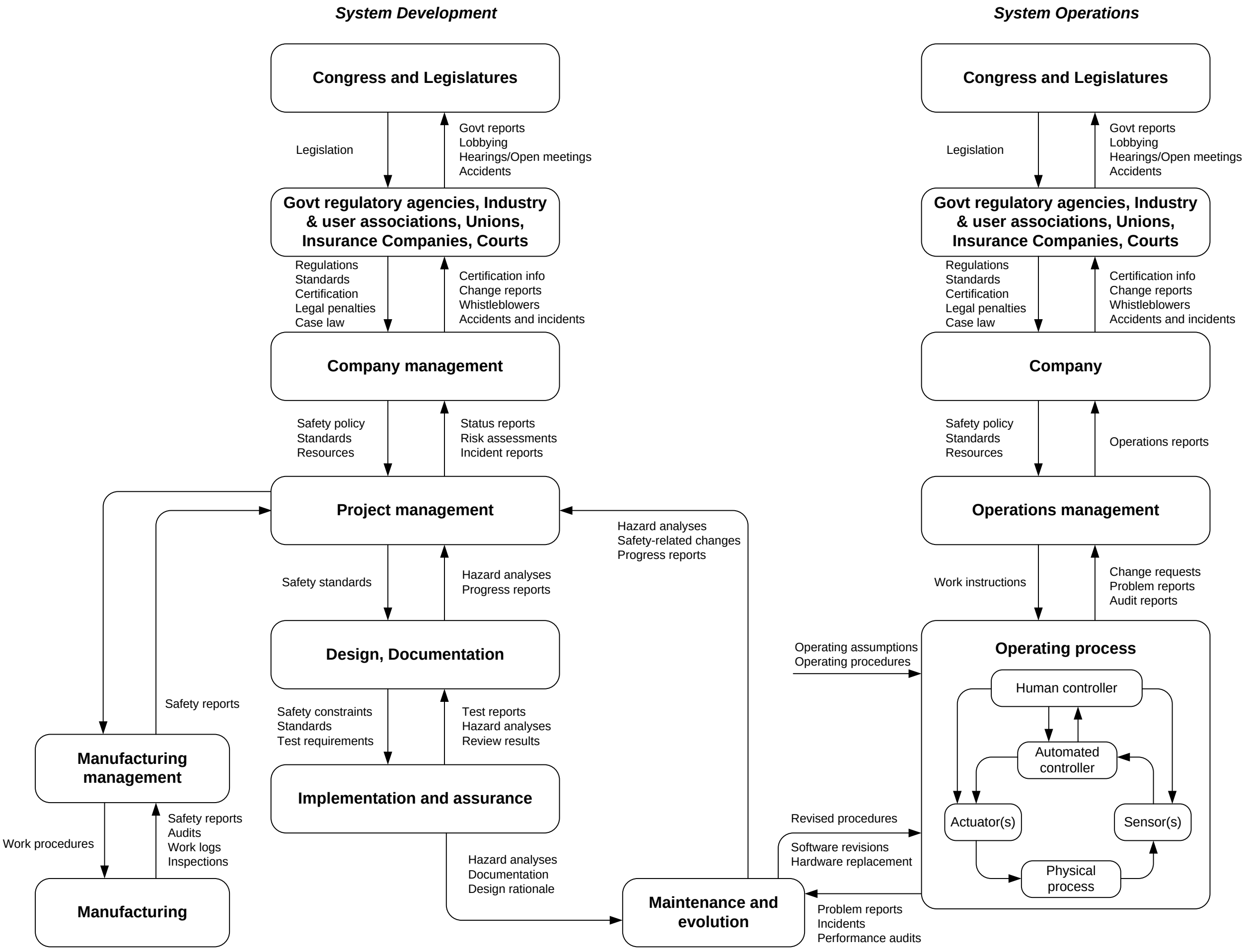

Figure 1. Generic control structure model

An overview of each level in Figure 2 is given below.

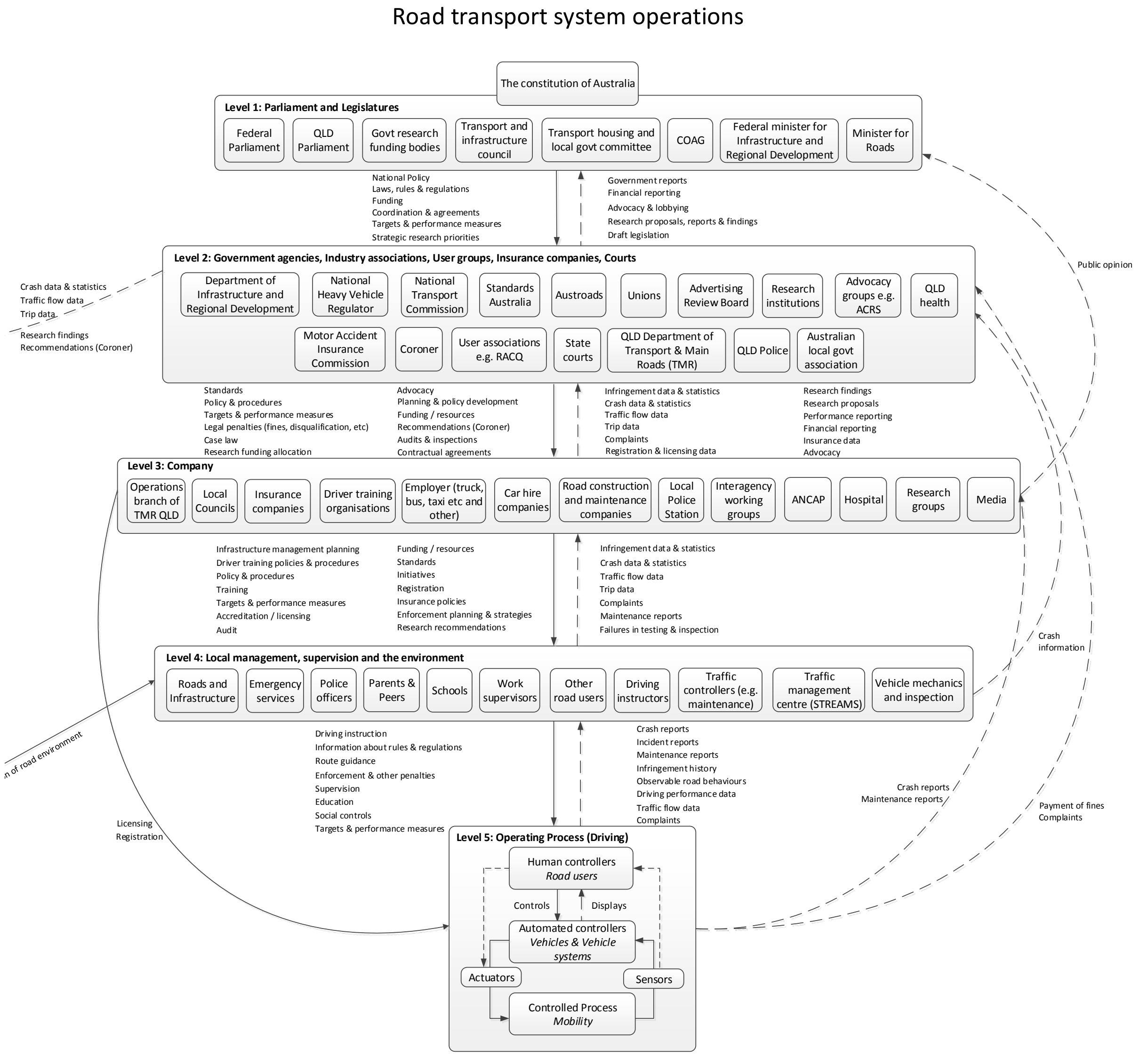

Figure 2. Control structure model of Qld road transport system (note the connections from the left hand side represent those from the road system design control structure)

Level 1 Parliament and Legislatures

Level 1 of the control structure represents the highest level of the Qld road transport system, comprising both federal and state governments and related agencies. At the top of this level sit the Constitution since it has the power to legislate for different aspects of road transport. Underneath the Constitution sit the state and federal parliaments, Ministers with transport portfolios, government committees and councils (including COAG – Council of Australia Governments) and federal research funding bodies (such as the Australian Research Council and the National Health and Medical Research Council).

Key control mechanisms enacted by this level include national policy (e.g. the National Road Safety Strategy 2020), laws, rules and regulations, funding for activities such as infrastructure management, road safety initiatives and research, coordination and agreements (e.g. the COAG inter-governmental agreement on cost shifting), targets and performance measures (e.g. road safety targets), and strategic research priorities.

The feedback mechanisms coming into this level include government reports covering issues such as the road toll and research findings, financial reporting, advocacy and lobbying, research proposals, and draft legislation.

Level 2: Government agencies, industry associations, user groups, courts

Level 2 of the control structure comprises government agencies, regulators, industry associations, user groups, and the courts. Actors and organisations represented at this level include federal and state government departments and statutory bodies, safety regulators, user and industry associations and courts, state Coroners and regulators such as the Motor Accident Insurance Commission (who regulates the compulsory third party insurance scheme in Qld) the Qld Police and National Heavy Vehicle Regulator.

There are various forms of control enacted by those at level 2 on actors and organisations at level 3, including standards (e.g. Australian Design Rules), road transport policies, procedures and codes of conduct (e.g. transport infrastructure asset management policy), targets and performance measures, legal penalties, case law, research funding, planning and policy development, funding and resources, coronial recommendations, audits and inspections, and contractual agreements (e.g. road maintenance contracts).

There are various feedback mechanisms informing level 2 about road transport system performance. Key mechanisms from level 3 to level 2 include reporting around infringements, crashes, fatalities and injuries, traffic flow and trips, financial performance, and registration and licensing. In addition, a key feedback mechanism for level 2 is research findings, whereby research groups provide reports and presentations to key road safety bodies such as Transport and Main Roads (TMR) Qld. Finally, insurance claims data is also fed up to the Motor Accident Insurance Commission by insurance companies

Level 3: Companies

The company level of the model includes organisations who are engaged in key road transport operations tasks such as licensing and registration, employment of professional drivers, and the allocation of safety ratings. In addition, research groups and the media are included at this level. These actors and organisations include the operational divisions of TMR, various employers of professional drivers, including freight organisations and public transport providers, ANCAP, hospitals, and road safety research groups such as the Centre for Accident Research and Road Safety (CARRS-Q).

The actors and organisations at level 3 enact the most number of control mechanisms within the model. Some of the key control mechanisms enacted on level 4 include infrastructure management planning, training (e.g. for professional drivers and driving instructors), policy and procedures around driver training and employment (e.g. working hours within freight organisations), accreditation and licensing (e.g. accreditation of driving instructors), registration, insurance policies, and road auditing. A key control mechanism enacted on level 4 is initiatives, which cover local initiatives developed with the specific aim of improving road safety (for example drink driving blitzes, education programs etc.).

The actors and organisations situated at level 4 in the model use a range of feedback mechanisms to update those at level 3. The feedback mechanisms used provide information regarding infringements, crashes, fatalities and injuries, traffic flow, and trips. In addition, complaints made to employers and local councils regarding safety issues provide a key feedback mechanism between levels 4 and 3, which in turn inform activities such as the development of initiatives. Finally, maintenance and inspection reports provide a key mechanism for level 3 actors and organisations to understand the condition of roads and vehicles.

Level 4: Local management, supervision and the environment

Level 4 in the control structure represents the road environment and the actors and organisations that either supervise or influence road user behaviour. This includes the road and road infrastructure, which comprises the road, road signage, road markings and road infrastructure such as traffic lights, roundabouts and median strips. The Police provide a key role at this level, effectively supervising road user behaviour, enforcing road rules and regulations, and providing a traffic control function when necessary. The emergency services are included as providing control mechanisms in the event of a road crash. Additional supervisory controls are provided by parents and peers, schools, and workplace supervisors (for professional drivers). Other important actors at this level include other road users (due to their influence on road user behaviour) and driving instructors. Traffic control mechanisms are facilitated by traffic management centres, which monitor traffic behaviour work with the police, emergency services, road maintenance organisations, and public transport providers to maintain network flow. Finally, vehicle mechanics provide critical control functions related to road vehicles.

The control mechanisms enacted by those at level 4 relate specifically to control of road user behaviour. The roads and road infrastructure provide information regarding road rules and regulations (e.g. speed limits) and route guidance, whilst the police officers enforce the road rules through monitoring and measuring road user behaviour (e.g. speeds), alcohol and drug testing, and issuing warnings and fines. Supervisory controls, such as monitoring driver behaviour, providing feedback on performance, and educational activities are enacted by parents, workplace supervisors, and schools. Finally, mechanics and vehicle inspectors ensure that road vehicles are performing to the standards required by road licensing rules and regulations.

The primary feedback mechanism coming into level 4 is offered by road users who provide specific information regarding road user behaviour and road system performance. These include crash reporting (e.g. driver statements to police and emergency services), incident reporting (e.g. drivers reporting to work supervisors regarding near miss incident), maintenance reports and infringement histories. Further important feedback mechanisms between levels 5 and 4 are observations of road user behaviour and driving performance and traffic flow data held by road cameras and traffic management centres.

Level 5: Operating Process (Driving)

The final level in the model incorporates vehicles and their human operators. At this level the driver exerts control over the vehicle and the vehicles systems provide feedback about the status of the vehicle and vehicle performance.

Discussion

The aim of this paper was to present a STAMP control structure model of the Qld road transport system. The analysis presented was undertaken in response to recent calls for a systems thinking approach to road transport system analysis (e.g. Larsson et al, 2010; Salmon and Lenne, 2015). A first step in initiating such an approach involves describing the range of actors and organisations that make up road transport systems along with the relationships that exist between them. This contribution will enable some of the interactions that give rise to emergent behaviours, such as the fatal five behaviours, to be described. The control structure model presented depicts the range of actors and organisations operating within Qld and outlines some of the key control and feedback relationships between them.

The model supports the perspective that the fatal five are a systems problem, as opposed to merely a driver problem. This is evidenced by the myriad actors and organisations that influence how the road transport system operates – driving occurs within a complex sociotechnical system in which the decisions and actions of many have an influence on behaviour. In line with systems thinking it may be more appropriate to treat the fatal five behaviours as *consequences* rather than *causes*. That is they may be the consequence of issues within the road transport system, and indeed wider society. This provides a different perspective and potentially offers different avenues when developing road safety interventions. A challenge for road safety research is to identify the issues than can be managed through road safety interventions.

A further contribution of the model is further clarification around who shares the responsibility for road trauma and the fatal five behaviours in Qld. The shared responsibility for road trauma is now widely accepted across Australian jurisdictions and attempts have been made to identify those responsible for road safety. Few, however, have gone beyond the major actors and organisations to describe who shares the responsibility across road transport systems, or to clarify what the responsibility entails in terms of core activities and behaviours. By detailing the range of actors and organisations involved in road system operation in Qld, the control model structure takes a step towards this. First, the actors and organisations are described, and second, the key roles that they play can be inferred by the control relationships and feedback mechanisms described. It can be concluded from this that a diverse set of actors and organisations share the responsibility for the fatal five behaviours and road trauma in Qld, covering the Constitution and government, government agencies, unions, research institutions, local government, road safety authorities, insurance groups, driver trainers, advocacy groups, the police and emergency services, road users, parents and peers, and schools to name only a few. Notably, there are others involved in the design of road systems not described in Figure 2; however, the additional road system design control structure developed by the authors covers these actors and organisations. Key future research requirements involve examining actors' and organisations' perceptions regarding their roles and responsibilities in road safety along with the range of activities that they undertake to fulfil this. In turn, this will highlight further control and feedback mechanisms to add to the model. A final implication of this finding is that interventions designed to improve behaviour and performance may also be fruitful when aimed at the higher levels of the road transport system. For example, improved performance and interactions at the higher levels of the system around policy development and implementation will have positive effects at the lower levels.

An interesting aspect of the model is the different forms of control mechanism described. Leveson (2004) describes various forms of control, including managerial, organisational, physical, operational and manufacturing-based controls. Although STAMP was developed for more typical process control-based systems, it is interesting to note that all of forms of control outlined by Leveson (2004) are extant in the Qld road transport system (although manufacturing-based controls are present only in the road transport system design control structure not presented in this paper). For example, managerial and organisational controls are present through the government at the higher levels of the system and also organisations who employ professional drivers. Whilst the higher levels are characterised by managerial and organisational controls, the lower levels require more physical controls in the sense that road users need to be controlled when operating on the road. For example, vehicles and the road infrastructure provide physical control over road users in terms of where they can go, who they can interact with, and how fast they can travel. In turn, road users provide physical control over vehicles and indeed other road users. Operational controls are provided by Police officers and road rules and regulations.

A final interesting feature of the model is the relative strength of the controls described, particularly when road transport is compared to other more heavily regulated transport systems such as aviation and rail. Despite ostensibly similar controls enacted across the different transport systems, it is apparent that some forms of control are weaker within road transport and consequently that there is more latitude for behaviour. For example, controls around driver impairment are stronger in areas such as civil aviation, whereby pilots have to comply with strict rules around alcohol consumption and are often tested for alcohol before flying the plane. Although road users are bound by rules and can be tested via random breath testing, the nature of the road transport system is such that the controls around alcohol are weaker and there is more latitude for road users to drive under the influence. Consequently drink driving continues to be a prominent factor in road trauma. The same can said for the other fatal five behaviours, (fatigue, speeding, distraction, failure to use seat belts) whereby other transportation systems have stronger more effective controls for similar issues through rules and regulations, performance monitoring, and procedures. A challenge for the road safety community is to strengthen the controls and influences enacted on road users whilst at the same time ensuring that they are practical to enact and do not become overly intrusive. It is likely that this will involve new forms of control rather than attempting to simply increase the frequency within which existing controls are enacted through avenues such as more random breath testing and more monitoring of road user behaviour and speeds. Rather, new approaches to preventing the fatal five behaviours may be required. The program of research from which this article derives is focussed on this line of inquiry.

In terms of practical implications, the control structure model raises questions regarding current road crash data collection and analysis systems. As discussed, the model depicts a vast range of actors and control relationships that share the responsibility for road trauma by designing and operation the road transport system. Underpinned by systems thinking, the analysis suggests that interactions between these actors and organisations can play a role in creating or enabling the fatal five behaviours and road trauma. In discussing road crashes, Salmon and Lenne (2015) modified Rasmussen's (1997) key tenets of systems thinking to apply to road transport systems. It was argued that road crashes are emergent properties impacted by the decisions and actions of all actors within the road system, not just by the road users alone. Likewise, the modified tenets suggest that threats to road safety are caused by multiple contributory factors rather than a single poor road user decision or action. Finally, it was suggested that threats to road safety result from poor communication and feedback across levels of the system. In light of these modified tenets and the control structure model, it is questionable whether current data collection and analysis systems are sufficiently identifying the contributory factors involved in road trauma. Even with the most in-depth crash systems, the knowledge base on the causes of key road crash causing behaviours is heavily oriented to contributory factors around drivers, their vehicles, and the road environment, with little information regarding less direct contributory factors residing at the higher levels of the system. The key to identifying these higher level contributory factors lies in examining the relationships and interactions between the actors and organisations residing at the higher levels of the road system. The development of systems thinking-based crash data collection and analysis systems is a key future research requirement that has previously been articulated (e.g. Salmon and Lenne, 2015) and further emphasised through this study.

As a first of its kind application in road safety the analysis revealed important methodological limitations when STAMP is applied in this context. One interesting feature of the control structure is the fact that many of the mechanisms identified may not in-fact represent controls per se, rather they may be closer to influencing factors. This finding is currently being explored further by the authors and could potentially lead to an extension to the STAMP method whereby differentiation is made between controls and influencing factors. A second limitation of the model relates to its inability to represent some of the wider societal influences on road user and road system behaviour. Ostensibly such influences represent key drivers underpinning the fatal five behaviours; however, the focus on control and feedback mechanisms ensures that it is difficult to incorporate such influences in the model. It is proposed that this provides one avenue for methodological development that will enhance the utility of STAMP in the road transport context.

It is worth noting that the model presented is in draft form, and that a Delphi study is currently being completed to refine and validate the model. This involves ascertaining road safety and systems thinking experts' feedback on the model. As such, issues surrounding debates over the placement of actors and organisations at different levels will be resolved. Notwithstanding this, further research clarifying the placement of actors and organisations in the model is recommended. Moreover, an additional line of inquiry involves examining explicitly the functions and systems in place, as opposed to merely the actors and organisations implementing them. Whilst the intention was to represent such functions through the control mechanisms between levels, it is acknowledged that further details will prove useful.

In closing, it is hoped that the systems thinking approach continues to gain traction in road safety circles. Applications continue to emerge in the literature and the findings are compelling (e.g. McClure et al, 2015; Newnam and Goode, 2015). Further applications of systems thinking in the road safety context are encouraged. It is these authors opinion that the rich outputs from such applications will support the optimisation of road transport systems along with the attainment of further road safety gains.

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Digital billboards 'down under': are they distracting to drivers and can industry and regulators work together for a successful road safety outcome?

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Abstract

In Australia, digital billboards are beginning to be permitted at the roadside. There are concerns, however, from a road safety perspective that these signs may have more potential to distract drivers than static billboards. Since the existing international research on digital billboards and driver distraction is inconclusive, an on-road study was conducted to compare drivers' eye fixations and driving performance when advertising signs (static billboards, digital billboards and on-premise signs) were present. A total of 29 participants aged 25-54 years were fitted with eye tracking glasses and drove an instrumented vehicle along a 14.6 km route in Brisbane, Queensland passing a number of advertising signs, including digital and static billboards and on-premise signage. Number of fixations and dwell times towards advertising signs were measured, along with lateral deviation and vehicle headway. The study found the average fixation durations for all signage types were well below 0.75 s, considered to be the minimum perception-reaction time to an unexpected event. There were no significant differences in average vehicle headway between the three signage types. There was a statistically significant difference in lateral deviation when billboards were present. Joint research between regulators and industry is needed to further explore these findings.

Introduction

In Australia, Out-of-Home (OOH) advertising is a legitimate and powerful means of advertising products and services. OOH advertising signs that appear on the side of the road such as billboards and bus shelters not only offer an effective means for advertising but also provide a potential revenue stream for State and local governments. As roadside billboards are designed to attract attention, an extensive body of research has explored whether roadside billboards have the potential to distract drivers or cause them to become inattentive to the driving task, which may ultimately lead to a crash (e.g.Decker, et al. 2015). In Regan, Hallet & Gordon's (2011) taxonomy, driver inattention has been defined as "insufficient, or no attention, to activities critical for safe driving" (p1775); while driver distraction (referred to as 'Driver Diverted Attention' in the taxonomy) is defined as the diversion of attention away from activities critical for safe driving toward a competing activity (either related or unrelated to the driving task), which may result in insufficient or no attention to activities critical for safe driving. As outlined in this taxonomy, billboards, because they are designed to attract attention, could compromise safe driving by diverting a driver's attention (either voluntarily or involuntarily) to a stimulus that is unrelated to the driving task.

Following substantial growth in the advertising industry over the last few years and advances in technology, digital billboards displaying a series of electronic advertisements are starting to be erected at the roadside. Subsequently, there are additional concerns that the size and brightness of the signs as well as the dwell time and changeover of each advertisement has the potential to divert attention away from the driving task for a longer period of time than a conventional billboard (Birdsall, 2008; Dukic, Ahlstrom, Patten, Kettwich & Kircher, 2013). In the interests of road safety, regulations and guidelines exist in most states of Australia for the installation of static billboards at the roadside. Operating standards for digital billboards are currently being drafted by regulators. The problem for regulators and the industry alike is that the existing scientific research cannot provide a definitive answer on whether billboards are sufficiently distracting to cause a crash, due to methodological limitations of the studies (e.g. Molino, Wachtel, Farbry, Hermosillo & Granda, 2009; Decker, et al. 2015) The current operating standards internationally also differ widely between jurisdictions, possibly due to this absence of sound research-based evidence (Molino et al., 2009).

The measurement of eye glances is often used to assess the degree to which drivers are not attending to the information relevant to safe driving (Perez & Bertola, 2011). It is generally accepted in the research on driver inattention that glances away from the forward roadway totalling more than 2 s doubles the near-crash and crash risk compared to normal baseline driving (Klauer, Dingus, Neale, Sudweeks, & Ramsey 2006). A number of studies (e.g., Beijer, Smiley & Eizenman, 2004; Chattington, Reed, Basacik, Flint & Parkes, 2009; Dukic, et al., 2013; Lee, McElheny & Gibbons, 2007; Smiley, et al. 2005) have investigated drivers' visual behaviour towards billboards in metropolitan on-road and simulated environments. These studies have generally found that the presence of billboards did not significantly affect the percentage of time drivers devoted to glancing at the forward roadway (Decker, et al. 2015). Long glances were defined as anywhere between 0.75 s, the minimum perception-reaction time to an unexpected event, such as a vehicle slowing in front (Smiley, et al., 2005) and 2 s, based on Klauer et al.'s (2006) study. Other research has explored the relationship between eye glance behaviour and driving performance variables such as lateral deviation and vehicle headway, as these variables are also considered to be indicators of distraction (e.g. Molino, et al., 2009) and can have a direct road safety impact. For example, high levels of visual and cognitive demand can result in a greater level of lane deviation and shorter headways (Östlund, Nilsson, Törnros & Forsman, 2006). However, studies that have explored the influences of digital billboards on driver performance variables such as lateral deviation and vehicle headway in a metropolitan on-road environment have reported mixed findings. For example, Lee et al. (2007) found only minor differences in speed and lane deviation between digital and static billboards which were located on straight interstate roads, while Dukic et al. (2013) did not find any significant changes in regards to speed, lateral placement of the vehicle or headway at any stage when drivers were passing digital billboards on a motorway.

There is no doubt that billboards add to the amount of external visual information presented to drivers; however drivers are exposed to a considerable amount of other visual information when driving, particularly along urban roads, some of which is relevant to the driving task (e.g., traffic signs), and some that is not. In some cases, roadside on-premise signs that advertise a product or service offered at that location are very similar to billboards in terms of their size, conspicuity, luminance, location and use of digital elements. It could be argued that these signs are designed to attract attention like billboards, yet they are often regulated differently. Only one research paper to date has reported comparisons of visual behaviour towards digital billboards with on-premise signs. Lee et al. (2007) found that there were no significant differences in glance durations between digital signs and on-premise comparison signs, some of which contained a digital element (average glance durations of 0.92 s compared to 0.87 s, respectively).

In meeting with representatives from the OOH industry and local and State government regulators to discuss the regulation of billboards in regards to road safety, a number of concerns with the existing research were raised and two of these were considered to be worth exploring in a new study. The main concern was whether the international on-road research exploring the impacts of both static and digital billboards on driver performance could be applied to Australian conditions, as a) no equivalent study had been conducted to date in Australia for comparison and b) regulations for billboards in Australia differ in some ways to those in other countries. The other concern was about the limited research on the influences of on-premise signage on driver performance, given there is a considerably higher number of on-premise signage than billboards in the Australian road environment. Given these concerns and that previous research (e.g. Molino et al., 2009) had recommended using an instrumented vehicle and eye tracking technology to study the effects of billboards on driving behaviour, the aim of the present study was to compare fixations and driving performance in the presence of static billboards, digital billboards and on-premise signs in an Australian on-road driving study, using the latest eye tracking technology. It was hoped that these research findings would assist in the development of future regulations and guidelines for both static and digital billboards as well as on-premise signage in Australia. The following research questions were proposed:

1. Do fixations and driving performance differ significantly in the presence of billboards (both static and digital) compared to on-premise signs?
2. Do fixations and driving performance differ significantly in the presence of digital billboards compared to static billboards?

Method

Design

The study utilised a within-subjects design to explore the relationship between drivers' viewing behaviours at OOH advertising signs and their subsequent driving performance. Signage type was the independent variable and viewing behaviour and driver performance were the dependent variables.

Participants

A total of 29 participants (13 male, 16 female) were recruited via telephone by a specialist recruitment agency. A further four participants were recruited for an initial pilot study to test the equipment and driving time of the proposed route. This number of participants is commensurate with other similar international on-road studies (e.g., Beijer et al., 2004). Participants were aged between 25-54 years (M = 36.1 years, SD = 6.4 years) and all held a valid driver's licence, with a minimum of five years' driving experience. Drivers aged below 25 years and over 55 years were excluded from the study as limited driving experience and scanning patterns particular to these age groups were considered to be possible confounding factors in the results (e.g., Beijer et al., 2004). All participants had normal or corrected to normal eyesight. They were unfamiliar with the driving route, as familiarity with the route can influence viewing behaviour (Beijer, et al., 2004). In the present study, unfamiliarity with the route was defined as either a) living outside the area by more than 10 kilometres, b) never driven the route, or c) not having driven the route in the last 6 months, similar to the definition in the Beijer et al. (2004) study. Participants were paid $100 for their involvement in the study. They were not informed about the specific nature of the study or the purpose of the instrumented vehicle until after the driving experiment was completed and were given the option to withdraw from the study at any time.

Equipment

The Mobile Eye XG eye tracking system was used to capture participants' natural viewing behaviour while driving. The system consists of a set of head-mounted eye glasses that tracks all types of glances and records these in both video and data formats. A 2010 model Toyota Corolla sedan with automatic transmission was used as the test vehicle. The vehicle was fitted with the Mobileye collision warning technology to record lateral deviation and vehicle headway. This system was customised so that the raw data was synchronised with the eye tracking data. Cameras were attached to each side mirror to record lane position and behind the rear-view mirror to record vehicle headway. A roof-mounted sensor provided GPS location information. The data from all the different technologies was integrated and recorded within the RaceLogic VBOX performance measurement system which was installed within the passenger glove compartment.

Route

The driving experiment took place along a 14.6 km section of road through Brisbane, Queensland, and its surrounding suburbs to Woolloongabba (see Appendix A for the route map). The route included multi-lane arterial roads, single lane local roads, city streets and a bridge crossing, with a predominant posted speed limit of 60 km/hr. This particular route was selected as it exposed drivers to the three signage types in both high and low density signage environments and at different points in the road environment (e.g., along a straight section of road, at an intersection, etc.); although the temporal spread of signage across all three signage categories was uneven along the route, The total driving time for each participant along the route and back to the starting point was approximately 90 minutes, depending on the amount of traffic. Data for each participant was only recorded from the start of the drive at Zillmere to the end of the route at Woolloongabba.

Procedure

Participants were met at a supermarket car park in Zillmere, a suburb on the outskirts of Brisbane. They were fitted with the eye tracking glasses and an individual calibration procedure was conducted to ensure accurate POG recording. Participants then did a short 20 minute practice drive in the Zillmere area to familiarise themselves with both the vehicle and the eye tracking glasses.

Following the practice drive, participants drove the study route only once. A facilitator was present in the front passenger seat of the vehicle to provide instructions and route guidance where required. A technician was also present in the rear passenger seat to supervise the use of the eye tracking system. Participants drove the route in off-peak traffic conditions between the daylight hours of 11 am and 2 pm. On completion of the experiment, participants completed a 10 minute survey to record their demographic information.

Data analysis

The three signage types were encoded in the present study as static billboards, digital billboards or on-premise advertising signs. Static billboards were defined as signs that display a static poster-type advertisement for a business that does not operate at the site of the billboard. Static billboards were either next to or visible from the roadway and generally measured greater than 25 square metres according to industry standards. Bus shelters and phone booths with advertising that measured less than 25 square metres were also included in this category. Digital billboards were defined as signs that display a series of electronic static advertisements for a business that does not operate at the site of the billboard. These signs measured 18 square metres according to industry standards and the advertisement changed every 10 seconds with a simple transition from one advertisement to the next in one second. On-premise advertising signs were defined as signs that are used by businesses to advertise their product or service on the site of their business (for example, a car sales yard using a portable VMS to advertise the sale of their cars). They varied in size and included digital elements in some cases. Advertising content of billboards and on-premise signs (including text size, graphics, etc.) was not recorded. Traffic signs were also encoded, although they were not included in any statistical comparisons to enhance statistical power.

Given the length of the route and the time it would have taken to analyse all of the video footage from each participant, the route was divided into eight segments of approximately one minute each in duration to compare participants' driving performance. . Since digital billboards were of particular interest in this study and there were only four of these signs along the route compared to the large number of both static billboards and on-premise signage, four of the eight segments were designed to contain one digital billboard each. These digital segments also included a mix of static billboards and on-premise signs. The remaining four segments contained a mix of both static billboards and on-premise signs and were roughly comparable to the four digital segments in terms of their length and characteristics of the road. Segments were also originally categorised into high or low signage density environments; however in order to maximise statistical power of the subsequent analyses, the segments were collapsed and comparisons were made between the three signage categories only. A total of 21 static billboards were located across segments for comparison with the digital billboards. On-premise signs were not counted due to the time consuming nature of the encoding task, though the number of these signs would be substantially higher than the number of both digital and static billboards.

Participants' viewing behaviour was analysed in terms of number of fixations and the duration of these fixations. Fixations were defined as the maintenance of visual gaze on a specific region or object in the visual field. Generally, dwell times of 200 ms are classified as fixations; however more recently it has been suggested that fixations shorter than 200 ms are possible (Manor & Gordon, 2003). In this study, the threshold for fixations was therefore set at 100 ms. For analysis purposes, fixations were categorised as either on road (i.e., the participant was looking at the road surface or traffic signs) or off-road (i.e., the participant was looking at a digital billboard, a static billboard, an on-premise advertising sign or something else off-road), Driving performance was analysed in terms of average and standard deviation of vehicle headway and average standard deviation of lateral position. These are commonly used as measures of distraction in other studies on billboards (e.g., Dukic, et al., 2013; Smiley et al., 2005). Vehicle headway was calculated by measuring the distance in time between the test vehicle and a vehicle directly in front. Standard deviation of lateral position was calculated by measuring the distance between the vehicle and the right lane marker..

To reduce any bias in the analysis, two highly trained encoders naive to the aims of the study analysed the footage frame-by-frame to determine where participants were directing their fixations. Each fixation was classified according to an agreed coding scheme. The observational encoding approach used was Mangold Interact, a specialist behavioural encoding software. Inter-rater reliability was calculated using both the kappa statistic and the intra-class correlation statistic, which has been used in other on-road studies (e.g., Hanowski, Olsen, Hickman & Dingus, 2006). The kappa coefficient was calculated using the fixation analysis, and found that the encoders were in substantial agreement with one another ($K=.689$, $p<.001$). The intra-class correlation statistic was calculated using the on-road dwell times and again found that encoders were consistent with each other ($r=.812$, $p<.001$).

Statistical analyses were carried out using the PSY statistical program (Bird, 2004) and a significance level of $\alpha = 0.05$ was applied. In some of the analyses, participants were excluded where there was insufficient data in every condition for comparison. Statistical comparisons were made between 1) digital billboards and static billboards to see if there were differences in fixations and driver performance when digital billboards in particular were present, and 2) billboards in general (by collapsing results between digital and static billboards) and on-premise signs to see if there were differences in fixation and driver performance when these forms of signage are present in the road environment.

Results

Driver viewing behaviour

Eyes on road

The study found that generally, participants tended to fixate most on the road ahead when driving. . When comparing on-road viewing behaviour between digital and static billboards, there was no significant difference ($F(1,26) = .905$, $p = .760$). There was also no significant difference in on-road viewing behaviour when billboards (both static and digital) were present compared to when on-premise signs were present ($F(1,26) = .808$, $p = .377$).

Fixations

A total of 1,553 individual eye fixations were made towards billboards (both static and digital) across all segments. The characteristics of the fixations made towards each signage type in the eight segments are displayed in Table 1. Whilst there were far more fixations on static billboards than on digital billboards, there were five times as many static signs than digital signs along the route. When comparing average fixation durations between digital and static billboards, the result was not significant ($F(1,568) =$

1.780, $p = .183$. The result was significant when comparing billboards (both static and digital) with on-premise signs ($F(1,550) = 4.809$, $p = 0.29$).The average fixation durations however are well below 0.75 s which is considered to be the minimum perception-reaction time to an unexpected event.

Table 1: Fixation characteristics by signage type

Sign type	Total fixations	Average fixation (ms)	*SD* (ms)	Median (ms)	Minimum fixation duration (ms)	Maximum fixation duration (ms)
Static billboard	426	225	178	165	99	2310
Digital billboard	144	207	120	165	99	891
On-premise	983	199	107	165	99	1056

In terms of long fixations, only 12 fixations were above 0.75 s, considered to be the minimum perception-reaction time to an unexpected event. Two of these fixations were made towards digital billboards, eight were towards static billboards, and two were towards on-premise signs. Closer inspection of the video footage would be required to determine the exact signs that received these long fixations. There was only one fixation of over 2 s recorded in the study, where the participant was looking at a static billboard; however on closer inspection of the footage, the vehicle was stationary at the time of the fixation.

Driving performance

Vehicle headway

Average vehicle headway for each signage type was calculated for across the segments. The average headway when billboards (both static and digital) were present was 1.80 s compared to 1.85 s when on-premise signs were present. This difference was not statistically significant ($F(1,20) = .335$, $p = .569$). Further comparisons on average vehicle headway were made between digital and static billboards to see if there were any significant changes when digital billboards were present. The average vehicle headway when static billboards were present was 1.82 s compared to 1.77s when digital billboards were present. This difference was also not statistically significant ($F(1,20) = .636$, $p = .435$).

Lane deviation

The average standard deviation of lane position (SDLP) for each signage type was calculated across the segments. There is great variability in the literature in regards to what SDLP is considered normal when driving, however it is estimated to be 0.20 m on average (e.g. GreenCullinane, Zylstra & Smith, 2004).When billboards (both static and digital) were present, the average SDLP was 0.38 m compared to 0.30 m when on-premise signs were present. This result was statistically significant ($F(1,27) = 23.846$, $p = < .001$). Further comparisons on average SDLP were made between digital and static billboards to see if the average SDLP increased in the presence of digital billboards. The average SDLP in the presence of digital billboards was 0.37 m, compared to 0.38 m when static billboards were present. This result was not significant ($F(1,27) = .333$, $p = .569$).

Discussion

This study compared drivers' fixations and driving performance when advertising signs were present in an on-road environment. Specifically, the study explored whether there were significant differences in the number and duration of fixations as well as any significant differences in vehicle headway and lateral deviation when 1) digital billboards were present compared to when static billboards were present, and 2) when billboards in general (both static and digital) were present compared to when on-premise signs were present.

The study found that generally, participants tended to fixate most on the road ahead when driving, which is a positive finding in terms of road safety. There were also no differences in this on-road viewing between the three signage types. These findings are similar to that of Lee et al. (2007). There could be several reasons for these results; however these are speculative due to the lack of self-report data. Firstly, participants' attention might not have been attracted to these signs, or they may have chosen not to look at them. Secondly, because participants were unfamiliar with the route, they may not have had the spare cognitive capacity to look at things outside of the driving task. It is unknown exactly where participants directed their fixations for the small percentage of time when their eyes were not on the road or why (e.g. their attention was attracted to a billboard; they were looking at a traffic sign, etc). Future research may wish to include a self-report questionnaire to gather this kind of information.

When participants looked at billboards and on-premise signs, the average fixation durations were all well below 0.75 s, which is considered to be the equivalent minimum-perception reaction time to the slowing of a vehicle ahead (Smiley et al., 2005), which is another positive finding in terms of road safety. Less than one percent of all fixations were above 0.75 s, and long fixations were found for all three signage types. There was only one fixation of over 2 s, which is considered to be the upper limit to which a driver can be distracted from the driving task (Klauer et al. 2006). The video footage was closely inspected for this long fixation only. In this instance, the participant was looking at a static billboard; however the car was stationary at the time of the fixation. While some participants did make a small number of long fixations between 0.75 s and 2 s, the results seem to suggest that participants were generally concentrating on the driving task. Participants may have also only made these longer glances when the driving conditions permitted; for example, when the car was stationary. Closer inspection of the video footage would shed more light on whether this was the case or not. It is also unclear as whether the features of the sign (e.g. size, advertising content) might have led participants to fixate longer on these signs. This would be very hard to measure in an on-road experiment as each sign along the route differs in terms of its size, advertising content and features of the surrounding environment (e.g. located at an intersection or along a straight stretch of road).

In regards to driver performance variables, the data showed no significant differences in average vehicle headway for any of the signage types.. The average vehicle headways for the three signage types ranged from 1.77 s to 1.85 s, which falls amongst the preferred headway of most drivers (Ayres, Li, Schleuning & Young, 2001). Since the time of perception-reaction to an unexpected event can take up to 1.6 s (Smiley, Smahel & Eizenman, 2004), the headways found in the present study would have given drivers enough time to detect the slowing of a vehicle in front and respond accordingly.

The data did show a significant difference average SDLP when billboards (both static and digital) were present compared to when on-premise signs were present. This is similar to the trend shown in the studies conducted by Lee et al. (2007) and Chattington et al. (2009), suggesting that billboards may have an impact on lane keeping when they are present along a driving route. There was no significant difference in average SDLP when digital billboards were compared with static billboards. This might be because digital billboards were attended to in similar ways to static billboards, even though they operate differently in terms of the display and changeover of the advertisement. Clearly, large SDLP values are of concern from a road safety perspective as they can cause a driver to depart from the lane, therefore increasing the chances of a crash (Peng, et al., 2013). There were no lane departures in the present study, but what remains to be defined is how much lateral deviation is considered dangerous and could lead to potential lane departures. Research has found that lateral deviation can differ greatly between drivers (Verster & Roth, 2011); however under normal baseline driving conditions, it is estimated to be around 0.20 m (Green et al., 2004; Verster and Roth, 2011; Zhou et al., 2008), with values ranging from 0.09 m up to 0.30 m and higher. It should also be noted that on-premise signs had a higher SDLP compared to the SDLP for normal baseline driving. Future research on the impacts of SDLP by signage in general (including on-premise and traffic signage) would be warranted.

There are a number of limitations to the present study in addition to the ones already highlighted in this discussion. Firstly, the study would have been more robust if there had of been a true control condition where no advertising signs were present; however because the route was chosen due to the number and location of digital billboards, no equivalent comparison segment could be found along the route to use as a control. Also, because the segments were of approximately one minute in duration each, it is possible that true driving behaviours may not have been reflected in such short periods of time. SDLP in particular has been found to be affected by trip duration (Zhou et al., 2008). Secondly, although it is clear from the video footage that the number of on-premise signs and traffic signs far exceeds that of billboards, an exact number of these signs could not be provided at the writing of this paper due to amount of time it would take to classify and categorise this signage. Thirdly, due to sample size and number of variables, comparisons were unable to be made in regards to signage density, which can have an influence on fixations. Comparisons were also unable to be made between traffic signage and advertising signage for the same reasons. This would have been interesting analyses as traffic signs are relevant to the driving task, whereas advertising signs are not. Fourthly, other than the operational characteristics of digital billboards, other signage characteristics such as size, advertising content, luminance, exposure and roadside position were not explored as they differ greatly and would have likely confounded the results. The digital billboards in this study displayed static electronic advertisements, so no conclusions can be made about digital billboards that display moving or animated advertisements. Also, signs that were located at traffic signals may have influenced results as the behaviour of participants who were stopped at a red light might have been different to those that had to keep driving through a green light. Lastly, the study only sampled middle-aged drivers, so the results may not be able to be generalised to younger and older drivers, who may show even greater variability in the driver performance variables.

Conclusions

To the author's knowledge, this study is the first Australian on-road study to explore differences in drivers' eye fixations and driver performance when billboards and on-premise signs are present. Despite some limitations, the results show similar trends to those reported in other international studies. In regards to the two research questions, the findings firstly show that fixations and average vehicle headway were similar when on-premise signs were present compared to when billboards were present. Although there was a significant difference in average SDLP when billboards were present compared to when on-premise signs were present, the average SDLP for on-premise signs is still higher than what is considered normal for baseline driving. Whilst it is unclear if this is because on-premise signs function in similar ways to billboards or for some other reason, on-premise signs should be included in future research studies to further explore their impacts on road safety. Secondly, the findings show that digital billboards do not draw drivers' attention away from the road for dangerously long periods of time compared to the other signage types, and drivers maintained a safe average vehicle headway in the presence of these signs. Whilst average SDLP increased in the presence of billboards generally, digital billboards were not solely responsible for this result. Numerous suggestions are made for future research projects.Given that digital billboards are now a part of the urban landscape and that both the industry and regulators want these signs to exist without causing a serious road safety impact, it would make sense for these research projects to be conducted by regulators and the industry in partnership.. By working together to establish the facts, it will reduce the likelihood of research bias, increase the likelihood of acceptance of research findings and will lead to safe and reasonable operating standards for these signs.

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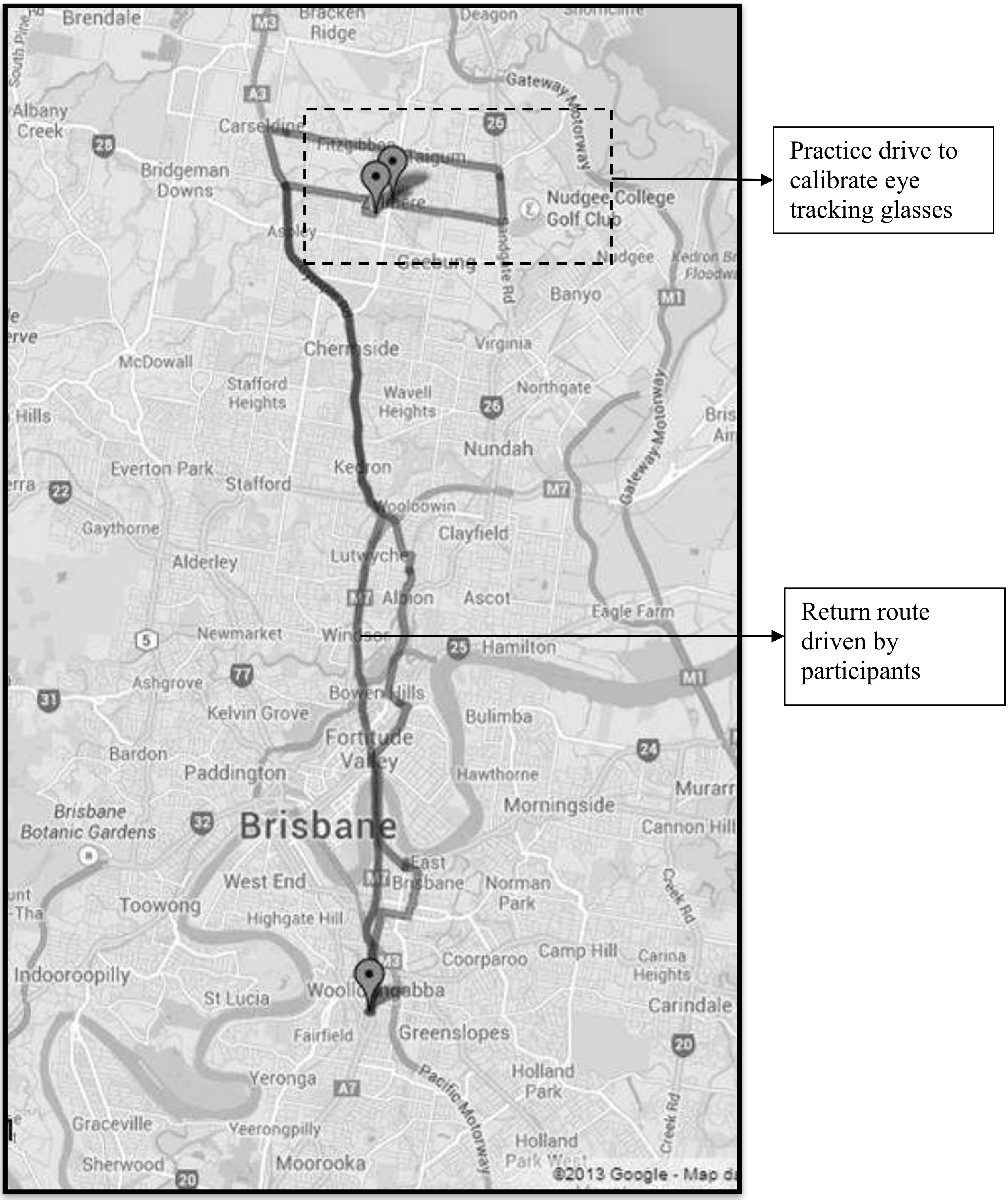
Appendix A


Practice drive to calibrate eye tracking glasses
Return route driven by participants
Brendale
Albany Creek
Bridgeman Downs
Carseldine
Nudgee College Golf Club
Geebung
Banyo
Chermside
McDowall
Stafford Heights
Wavell Heights
Virginia
Northgate
Nundah
Everton Park
Stafford
Kedron
Wooloowin
Clayfield
Gaythorne
Alderley
Lutwyche
Albion
Ascot
Eagle Farm
Newmarket
Windsor
Hamilton
Ashgrove
Bowen Hills
Kelvin Grove
Bulimba
Bardon
Paddington
Fortitude Valley
Hawthorne
Morningside
Brisbane Botanic Gardens
Brisbane
West End
East Brisbane
Norman Park
Toowong
Highgate Hill
Coorparoo
Camp Hill
Carina Heights
Indooroopilly
St Lucia
Woolloongabba
Carindale
Fairfield
Greenslopes
Yeronga
Holland Park
Graceville
Yeerongpilly
Sherwood
Moorooka
Gateway Motorway
Pacific Motorway
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Strengthening Local Road Safety Capacity in Cambodia

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Abstract

Road crashes and injuries have become a growing issue worldwide. In 2011, more than 75,000 people died in road crashes in the ten member countries of the Association of South East Asian Nations (ASEAN) and many times this number sustained long term injuries. In 2014, the Asian Development Bank (ADB), funded by the Japan Fund for Poverty Reduction, commenced a package of actions to improve road safety in ASEAN. In 2015, as part of the technical assistance for this project, a Road Safety Advisor was appointed for Cambodia for four months. The assignment produced several primary outputs, which included the organization of national training on traffic law enforcement and road safety management, the conduct of a training needs survey and cost analysis study, and the development of a proposal for strengthening speed management. It is important to note that unlike other ADB technical assistance projects, this assignment adopted a capacity building approach, which promoted and encouraged the local road safety team in the government to step up and take action. The research capacity building approach adopted in this project highlighted the feasibility of increasing participation from existing stakeholders, especially the government in identifying existing human resources, building the capacity of relevant government officials and supporting them to take the ownership of the project. It is hoped that similar outcomes will occur in the other ASEAN countries.

Introduction

The purpose of this presentation is to highlight the feasibility of strengthening local road safety participation in identifying existing human resources, building the capacity of relevant government officials and supporting them to take the ownership of a road safety project.

Road Safety in the Association of Southeast Asian Nations

Road crashes and injuries have become a growing issue worldwide, as evidenced by the publication of World Health Organisation reports in 2004, 2009 and 2013, and the launch of the UN Decade of Action for Road Safety in 2011 (WHO, 2004, 2009, 2013). Every year, around the world, 1.24 million people die due to road traffic injuries in addition to 20-50 million non-fatal injuries occurring (WHO, 2013). In 2011, more than 75,000 people died in road crashes in the ten member countries of the Association of South East Asian Nations (ASEAN) and many times this number sustained long term injuries.

Following the first initiative in 2004 to develop the ASEAN Road Safety Regional Action Plan and an of need for a more comprehensive and effective intervention, the Asian Development Bank (ADB), funded by the Japan Fund for Poverty Reduction, commenced a package of actions to improve road safety in ASEAN. This technical assistance aimed to strengthen the capacity of governments in addressing national and regional road safety issues in the ASEAN. It delivered six main outputs, which were: (i) strengthened capacity to monitor and analyse road accident data, (ii) strengthened capacity to implement road safety strategies, (iii) strengthened capacity to address motorcycle safety issues, (iv) improved enforcement capacity of traffic police, (v) a pipeline of road safety projects, and (vi) knowledge products disseminated publicly.

Road Safety in Cambodia

Cambodia is one of the ten countries to benefit from this technical assistance. The country is located in the southwest of the Indochinese peninsula, bordered by Vietnam to the east, Lao PDR to the north, and Thailand to the west. It is one of the poorest countries in the world, being ranked 136th out of 187 countries in the UN’s Human Development Index and 20.5% of the population live below the national poverty line (*Human Development Index*, 2014)

The numbers of road fatalities have been increasing every year since 2006, when 1,292 were recorded. In 2013, the National Road Safety Committee reported 1,950 fatalities and 14,277 injuries. With a total population of 14.67 million (an increase of 13% between 2005 and 2013), the fatality rate per 100,000 inhabitants in Cambodia was 13.2, compared with 10.2 in Vietnam and 13.4 in Lao PDR (National Road Safety Committee, 2014).

In 2013, road crashes led to an annual economic cost of USD 337M, equivalent to 2.1% of the gross domestic product (National Road Safety Committee, 2014). The crashes affected mostly young road users and especially students, workers and farmers, who play important roles in the country’s economic development (National Road Safety Committee, 2012).

The findings from the data analysis also indicated that road crashes tend to impact on poorer communities more, those who were pedestrians or travelled on motorbikes and bicycles, and those living in rural areas. Speed was reported as a major human error factor that is responsible for more than half of the fatalities and long term injuries.

Road safety as a concept was brought into Cambodia and introduced to the Cambodian government through a small project initiated by Handicap International in 2002 and the Regional Road Safety Program, supported by the Asian Development Bank in 2003. In 2005, the government approved the first 2005-2010 National Road Safety Action Plan, which aimed to prevent road crashes and promote safer behaviours among road users. This national plan was developed based on the ADB regional strategy. Two years later, the National Road Safety Committee was established with the specific task of coordinating and implementing the national plan. By the end of 2010, some important results in nine out of all fifteen actions were partially achieved:

- Action 1: Establishment of a National Road Safety Committee: was set up in 2007
- Action 2: Road Accident Data Systems: a Road Crash and Victim Information System (RCVIS) was initiated and implemented with a nationwide coverage in 2006
- Action 6: Road Safety Education for Children: primary and secondary school curricula on road safety were developed and extended to selected provinces
- Action 7: Traffic Law and Regulations: the traffic law was updated and approved by the government in 2006.
- Action 8: Law Enforcement: enforcement training courses were conducted and enforcement operations by traffic police teams were undertaken on helmet and drink driving in Phnom Penh
- Action 11: Emergency Assistance to Traffic Victims: emergency projects were introduced in Phnom Penh and Kampong Speu by two international organizations, but with limited scope
- Action 12: Road Safety Public Campaigns: many public awareness campaigns were organized throughout the years on helmet wearing promotion, mostly in Phnom Penh
- Action 14: Road Accident Costing Evaluation: a road crash cost analysis study was conducted in 2009

Although the first National Road Safety Action Plan was initiated by the ADB, no further support was provided after the development of the action plan. The implementation of the plan was then partially supported by several nongovernmental organizations. There were some achievements during 2005-2010, after the introduction of the first Road Safety Action Plan. At the same time, some challenges and obstacles were observed. First, all of the projects mentioned in the actions above were initiated and implemented by nongovernmental organizations. Collaborations and participations were observed during implementation, but government teams did not fully mange the process. This led to limited knowledge transfer in term of strategy development and project management. Second, the resources of these nongovernmental organizations were limited, compared to the specific project needs and the growing road safety issue in the country. For example, in 2010, a total of USD 0.8M was allocated by these organizations for road safety, compared to an annual economic cost of USD 279M due to road crashes in the same year (Sann, Gnim, Phan, Morrison, & Jong, 2012). The majority of the implementation occurred in Phnom Penh only.

In 2015, as part of the technical assistance for this project, a Road Safety Advisor was appointed for Cambodia for four months (the first author). The assignment produced several primary outputs, which included the organization of national training on traffic law enforcement and road safety management, the conduct of a training needs survey and cost analysis study, and the development of a proposal for strengthening speed management. It is important to note that unlike other ADB technical assistance projects, this assignment adopted a capacity building approach, which promoted and encouraged the local road safety team in the government to step up and take action. Rather than having a separate consultancy team, the government team worked with the Road Safety Advisor, with support from the project team leader, to deliver those outputs.

A team of four people from the government received a two-week comprehensive training program on road safety management, enforcement, community based promotion, motorcycle safety and data systems. Following training, they were technically and financially supported to organize two national workshops in Cambodia. One of their tasks was to review all training materials and be able to deliver them in Khmer language. They then progressively took the lead in meetings and other project activities, such as conducting cost analysis, to build up their knowledge of the project concept.

In particular, the development of the speed management proposal included various consultation meetings with relevant stakeholders from government institutions as well as non-governmental organizations. Speed was identified and proposed as the key priority for this proposal through evidence-based consultation among all partners and from the annual road crash report. The government team facilitated the consultation process, which included brainstorming ideas, proposing a strategy and developing the project framework. It was the first proposal developed by the national team, in collaboration with various stakeholders for speed management.

Conclusion

The research capacity building approach adopted in this project highlighted the feasibility of increasing participation from existing stakeholders, especially the government in identifying existing human resources, building the capacity of relevant government officials and supporting them to take the ownership of the project. It is crucial to involve the government from the early stage of the project design and to lead the consultation process among other road safety governmental and civil society stakeholders. This project filled a gap in the ADB project cycle, since it has contributed to the local capacity building for the government team and Road Safety Advisor, who are not international consultants. It strengthened the involvement and participation of road safety related stakeholders beyond the preparation stage (the development of the speed management project proposal). It is hoped that similar outcomes will occur in the other ASEAN countries.

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A practical methodology using in-depth crash data to support the assessment of new motorcycle safety technologies

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Abstract

Current knowledge on safety technologies developed for passenger cars represents great potential for translatable solutions that may also reduce the number and the severity of casualties among motorcyclists. However, the translation of a safety system conceived for a four-wheeled vehicle to a motorcycle is not straightforward due to the different characteristics in the vehicle dynamics and in common real world crash scenarios. In this paper, we present a methodology to exploit in-depth motorcycle crash data for the purposes of a subsequent assessment of the potential benefits of a promising safety technology for motorcycles: autonomous emergency braking (AEB). The in-depth crash data used in this study involved motorcyclists who were seriously injured following a crash on a public road within 150 km of Melbourne, Victoria. From the subset of cases available for this activity, a set of 20 multi-vehicle crashes in which AEB was considered as "possibly applicable" were identified using a dedicated rating algorithm. For each selected case, the trajectories of the host motorcycle and the other vehicle prior to the crash were estimated using the available in-depth data and reconstructed via 2-dimensional simulations. Finally a panel of investigators reviewed each case until agreement was reached on the accuracy of the reconstruction. In further steps of this research, AEB will also be modelled in the numerical environment. Simulations with and without assistance of AEB will be run to predict the effects that this safety technology may have produced in the reconstructed cases.

Introduction

Recent vehicle-based safety technologies developed for passenger cars show great potential for reducing serious injury crashes. These technologies may also offer significant safety benefits when applied to motorcycles. However, the translation of a safety system conceived for a four-wheeled vehicle to a motorcycle is not straightforward due to the different characteristics in the vehicle dynamics and differences in common real world crash scenarios. There is currently limited information available on the potential benefit of these safety technologies if applied to powered two-wheelers.

One of the most promising vehicle safety technologies is autonomous emergency braking (AEB) (Budd et al., 2015). In this paper, we present a methodology to exploit in-depth data from real-world motorcycle crashes for the purposes of a subsequent assessment of the potential benefits of this safety technology for motorcycles. The methodology presented hereafter is an important part of the assessment methodology previously presented by the authors (Savino et al., 2014).

Methods

The in-depth crash data used in this preliminary study were extracted from a recent case-control study. Cases were motorcyclists who were seriously injured following a crash on a public road within 150km of Melbourne, Victoria (Day et al, 2013). Recruited riders participated in an interview-based questionnaire. This was followed up with an investigation of the crash site and motorcycle. From the subset of cases available for this activity, a set of 20 crashes in which AEB was considered as "possibly applicable" were identified using a dedicated rating algorithm (Figure 1).

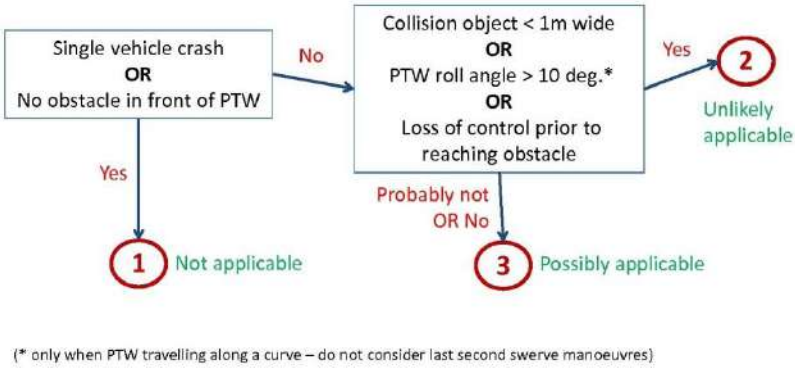

Figure 1: Algorithm for the evaluating MAEB applicability

For each selected case, the trajectories of the case motorcycle and the other vehicle prior to the crash were reconstructed via numerical, 2-dimensional simulations.

Initial speeds, vehicle headings, and modelling of the manoeuvres involved in the trajectories were estimated using the available in-depth data. Finally a panel of investigators reviewed each case until agreement was reached on the accuracy of the reconstruction.

An example case applicable to MAEB is summarized in the textbox below (see also Figure 2). The example shown was the most frequent reported scenario (defined by VicRoads DCA code) from the full series of recruited cases, which involves another vehicle turning right across the path of a motorcyclist travelling from opposite direction through an intersection.

CASE #129 (example)

Basic Crash Scenario (Rider questionnaire/self-report)

- M/cycle approaching traffic controlled intersection (middle lane)
- Lights began to change to red. Rider states intersection too close to stop on wet road
- Car travelling in opposite direction commenced right turn into the path of m/cycle
- Rider applied front brakes only, then swerved to avoid vehicle
- Rider struck vehicle, catapulting off car onto footpath (25m – site inspection)
- Visual obstructions: No (rider perspective)
- Weather conditions: Light rain, wet road
- Lighting conditions: Dusk/dark, Street lights ON
- Road Surface: Wet (confirmed)

Basic Crash Details (Site & Bike Inspection)

- DCA code 121 – 'right through' crash, motorcyclist as 'through' vehicle
- Est. travel speed of motorcycle (approaching int): 55-67 km/hr (70% confidence)
- Excessive use of brake: No
- Anti-lock brakes fitted: No (from bike inspection)

Basic Simulation details

- Initial PTW assumed: 61 km/h.
- Other vehicle (car) speed assumed: 30 km/h, decreasing to 12 km/h (accel. 0.2 g)
- Car turning radius = 16m

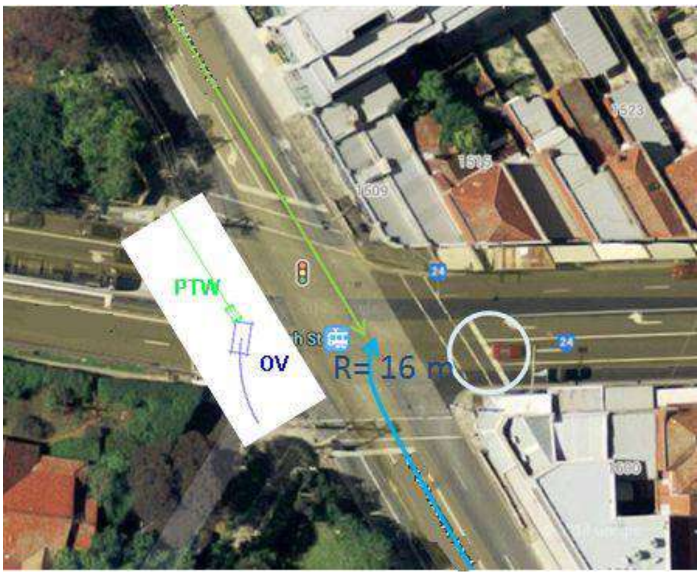

Figure 2: Example crash scenario (left) and photo of case motorcycle (right) used to assess the potential of AEB on crash likelihood or impact speed

Discussion

Kinematical and dynamical reconstructions of real-world road crashes are common activity and typically involve dedicated software. These reconstructions typically require many details including information from all vehicles involved regarding estimated initial speed, final position, and impact damage. In this study we applied a different approach, using a simple but very flexible software that we developed to focus on geometrical trajectories of the approaching vehicles, i.e. their time variant relative heading and speed. These are in fact the fundamental elements required to evaluate whether an obstacle detection system will detect an approaching vehicle, and the possibility for a triggering algorithm to compute the deployment of a given safety system. This approach, combined with the Monte Carlo methodology presented in Savino et al. (2014), should also allow coping with a lack of detail in a crash investigation, such as the exact final position of the vehicles involved or even any detail about one of the vehicles.

For these purposes, we believe that the information from the 20 selected cases (questionnaire and site inspection) together with the input of the crash investigator in panel discussions, were typically sufficient to model the crash scenarios for the purposes of assessing AEB. In fact, clear incongruences in the final trajectories and the crash report data were not reported in the process, and the team was able to reached reasonable agreement on each of the reconstructions.

Some limitations exist with this approach. Errors in the trajectory reconstructions may have occurred, especially in the cases with a very low level of detail available from the crash site, missing information in the questionnaire, or unfaithful responses. In some of these cases, the team may have misjudged the precipitating or primary factors involved in the crash, thus potentially leading to wrong decisions in the definition of the pre-crash trajectories or actions (both quantitative, but also qualitative errors). This is something to keep into account when moving on to the next step of evaluating the potential of AEB. However, the method proposed by Savino et al. (2014) is especially designed to handle quantitative uncertainty in the reconstructed pre-crash trajectories.

In further steps of this research, AEB will also be modeled in the numerical environment. Simulations with and without assistance of AEB will be run to predict the effects that this safety technology may have produced in the reconstructed cases, including any changes in crash likelihood or impact speeds.

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Road Safety Barriers
International experiences and new directions for Australia

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Abstract

Australian road fatalities may have halved since 1990, but all is not well. Australian fatality reduction has plateaued where our international peers see continued decline (BITRE, 2014-1). Serious injuries from road traffic accidents have been suggested to be on the rise (ITF, 2014). And if you're a crash statistic in Australia – you're three times more likely to be a fatality than in the UK, Canada, Germany or Sweden (BITRE, 2014-2). So are there lessons to be learnt from abroad? Australian road safety experts agree better infrastructure, and specifically road safety barriers, are part of the new solution (BITRE, 2014-3). This paper focusses on European (EN1317 compliant) safety barriers, which are lesser known in Australia than NCHRP-MASH compliant barriers. We present European experiences and state-of-the-art development directions that may help Australian road designers, specifiers and authorities make roads safer. We suggest EN1317 compliant barrier systems offer a good direction for greater injury reduction on Australian roads, with economic incentives compared to other options.

Comparison of international standards

In order to improve and maintain highway safety, the design of safer roads requires, on certain sections of road and at particular locations, the installation of devices to restrain vehicles and pedestrians from entering dangerous zones or areas. The road restraint systems designated by international standards are designed to specify performance levels of containment and to redirect errant vehicles and to provide guidance for pedestrians and other road users. The most used standards worldwide are:

- Standard EN1317, valid and obligatory in European countries and accepted by many national authorities worldwide
- Standard MASH, former also NCHRP, valid and obligatory in the United States of America and accepted by many national authorities worldwide

These standards describe requirements and test parameters of vehicle road restraint systems but do not include national parameters of using road safety barriers. Specific National standards and regulation sort out the requirement on specific road sections national-wide.

The EN1317 and MASH standards differ in certain aspects. A short overview of differences and similarities are presented in Table 1 and Figure 1.

Table 1. Qualitative comparison of MASH and EN1317

MASH standard	EN1317 standard
Focus on break-through prevention and deformations of occupant compartment	Focus on passenger safety
No direct classification of performance levels	Classification of displacement/working width, vehicle intrusion and passenger safety in performance classes
Different test vehicle mix	Different test vehicle mix
Minimum installation length defined afterwards	Rollover of vehicles is prohibited
Focus on Structural adequacy, occupant risk and vehicle trajectory	Test length defines the minimum installation length of restraint system

To compare different test conditions of each standard the impact energy levels of the test parameters are mostly used.

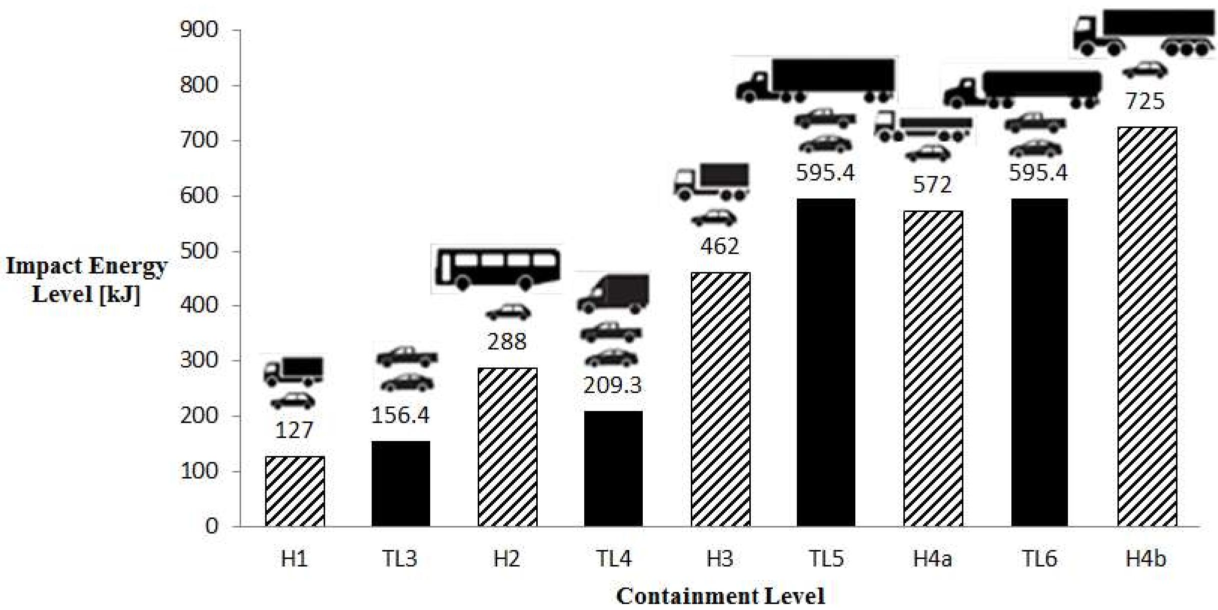

Figure 1. Containment levels and Impact energy levels of MASH and EN1317

Difference in design of safety barriers

Worldwide different design preferences exist. The reason therefore is mostly a historical background of less regulations and standards. Because of strict performance verifications by MASH or EN1317, a limitation of designs should not influence ongoing developments. The following designs are in general most popular:

- Single slope design – preferred in the USA
- Step profile design – preferred European wide
- F-shape design – preferred in the USA
- New Jersey design – preferred European wide

Verifiable passenger safety by ASI value classification

The standard EN1317 includes certain parameters for classifying the injury risk potential of passengers. The Acceleration Severity Index characterizes the intensity of the impact, and is regarded as the most important rate of impact on occupants. MASH acknowledges that measurement and/or calculation of ASI is preferable, but it is only prescriptive in EN1317.
The ASI value is an interaction and Correlation of different values:

- HIC – the Head Injury Criterion, measures the acceleration acting on the head of the occupants
- AIS – the Abbreviated Injury Scale, especially describes the injuries in head and neck area of occupants involved in collisions. Table 2 details the scale.

Table 2. Abbreviated Injury Scale

Injury Scale	Category	Injuries
0	None	No injury
1	Minor	Light brain injuries with headache, vertigo, no loss of consciousness, light cervical injuries, whiplash, abrasion, contusion
2	Moderate	Concussion with or without skull fracture, less than 15 minutes unconsciousness, corneal tiny cracks, detachment of retina, face or nose fracture without shifting
3	Serious	Concussion with or without skull fracture, more than 15 minutes unconsciousness without severe neurological damages, closed and shifted or impressed skull fracture without unconsciousness or other injury indications in skull, loss of vision, shifted and/or open face bone fracture with antral or orbital implications, cervical fracture without damage of spinal cord
4	Severe	Closed and shifted or impressed skull fracture with severe neurological injuries
5	Critical	Concussion with or without skull fracture with more than 12 hours unconsciousness with haemorrhage in skull and/or critical neurological indications
6	Fatal	Death, partial or full damage of brainstem or upper part of cervical due to pressure or disruption, fracture and/or wrench of upper part of cervical with injuries of spinal cord.

There is a correlation between AIS and the Injury Scale as Figure’s 2 and 3 demonstrate.

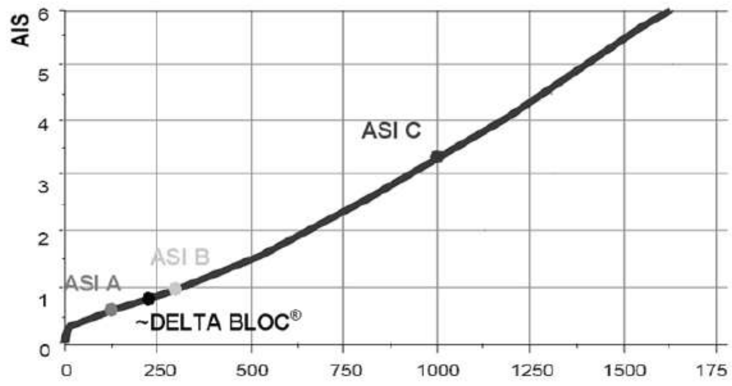

Figure 2. Correlation between AIS and HIC

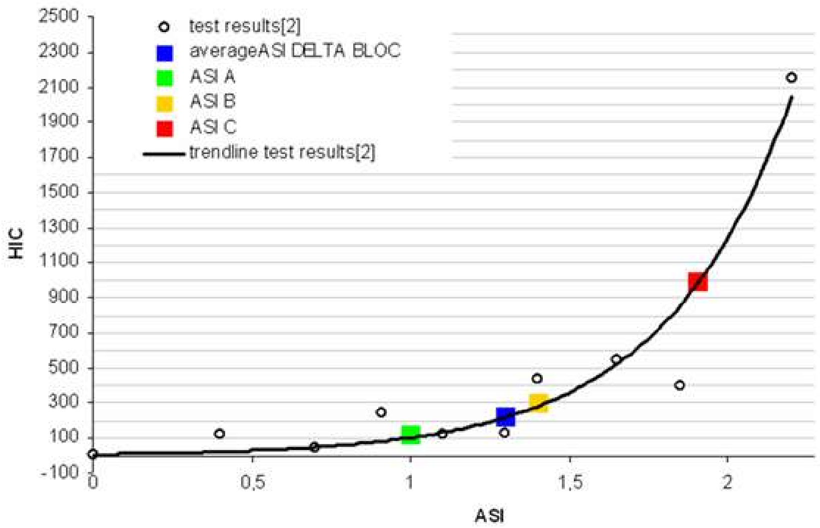

Figure 3. Correlation between AIS and HIC

As a result of the correlation between these values the performance classes ASI A and AIS B can be classified as providing high passenger safety with minor influences for occupants. Performance class AIS C in the contrary is classified as area of serious injury potential and is not approved in most countries.

State of the art technology

In recent years, the demands on traffic restraint systems have changed dramatically. The higher volume of traffic, the increased use of traffic management systems as well as the claims in the area of occupant protection and system space requirement flow strongly to development of new traffic restraint systems excessively.

Modern requirements

- Low space requirement: slim design, small working width, small displacement
- High safety performance: high containment classes H1-H4b / TL4-TL6, high passenger safety
- Economical and simple installation: optional freestanding barrier, over-night installation, short traffic interference
- Connectable system solutions: customised solutions supported by one supplier, transition solutions for existing barriers, wide product range for each application area
- Dual use options
- Reliable safety confirmed by international valid test reports

Dual use of traffic safety barriers

A great economic advantage represents mainly so-called dual-use products. Because of extensive tests these products are suitable for temporary protection as well as for permanent protection. This results in great savings potential for the user in the overall consideration. Figure’s 4 and 5 demonstrate how the same dual-use barriers can be utilised in both construction and normal service. In normal service, the dual-use barriers are embedded or pinned into the road surface to meet permanent barrier protection requirements.

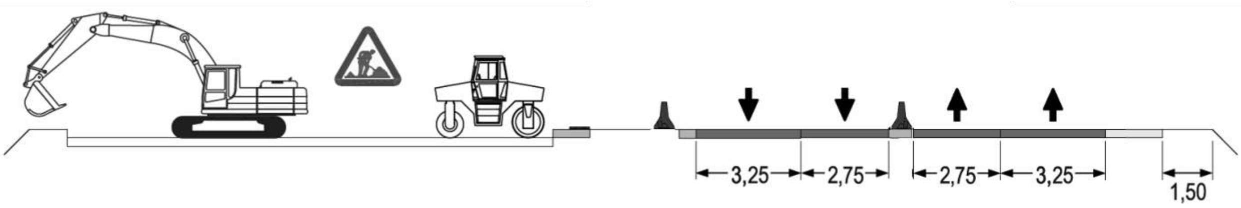

Figure 4. Example of road work zone during road refurbishment

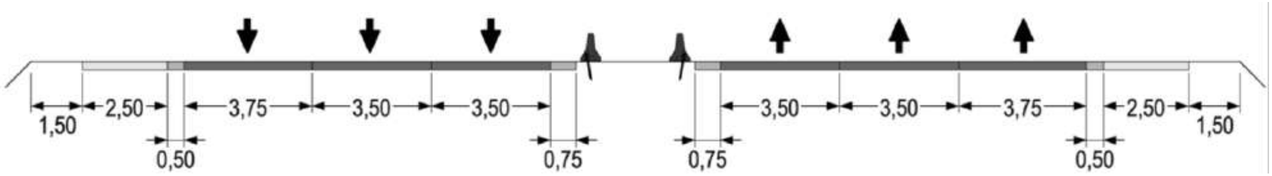

Figure 5. Final position of road safety barriers after road refurbishment

Durability of traffic safety barriers

The average period of use of restraint systems has changed dramatically through the increased use of high quality materials and technologies in recent years. Systems made of concrete currently have best properties in terms of resistance and durability. Light and medium impact events over the period of use are the greatest burden on restraint systems, and are by far the most common as Figure 6 shows. Most of these light and medium impacts however only marginally affect concrete barrier aesthetics, and not function. High resistance of products and avoiding of impact consequences by bad impact behaviour will be also a benefit directly for road users by low vehicle damage. Furthermore, traffic jams as a result of an impact will be greatly reduced.

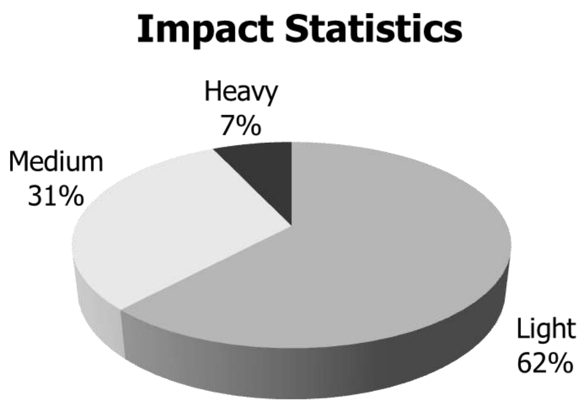

Figure 6. Impact statistics overview of heavy impact ratio

Customised solutions for special application areas

Standards like the EN1317 and MASH include only test parameters for products installed in a straight line. Therefore even curve radii situations are not supported by separate test parameters. In practice a modern highway section includes a lot of special application areas which requires customized solutions. The planers and authorities are requested to sort out the best provided solution of suppliers and to release them separately by project. Following solutions are well used in European countries.

Integration of lamp posts

For integration of lamp posts on motorways different options exist but in the case of small space conditions there is only one option: direct connection of the lamp post to the safety barrier as Figure 7 shows. Precast concrete barriers offers flexibility in design of cable releases and fixation plates. The element weight of the barrier supports specific demands on stability without fixation.

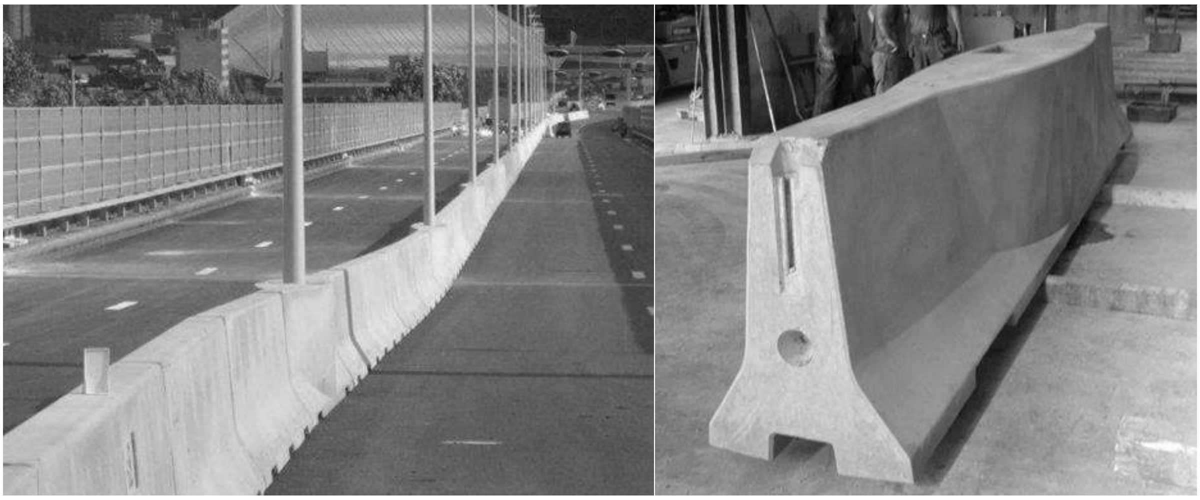

Figure 7. Example of precast concrete barrier solution with integration of lamp posts

Expansion joints on bridges

Expansion joints are part of most bridge constructions up to a certain dimension. Modern restraint systems also have to provide a continuous crash tested connection in these areas. Customized solutions can be provided up to certain expansion joint dimensions by mechanical means. However the integration of hydraulic dampers may be required for larger expansion joints as pictured in 8.

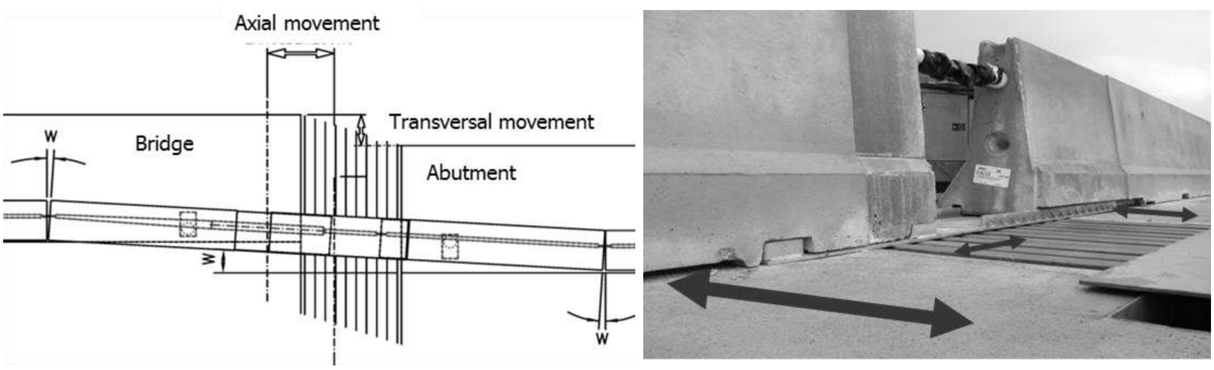

Figure 8. Requirements (left) and special system for expansion joints on bridges (right)

Combined system solution – noise protection / safety barrier

Noise protection close to urban areas becomes more and more of a priority. In the past, only separated products were available. Now there are new products which offer safety in both directions with small space requirements – see Figure 9. New developments of combined products are meeting the demands of today's market.

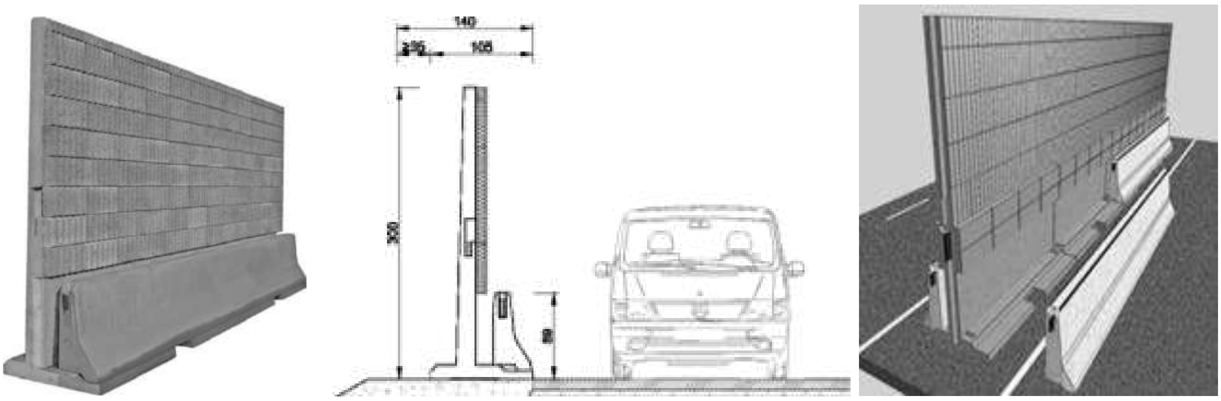

Figure 9. Combined system solution DB LSW tested in accordance with EN1317

Combined system solutions (tested by EN1317 and EN1793) can be placed close to the source of noise, and increasingly with absorptive, not reflective, noise wall technolog. This opportunity may remove the need for big noise protection walls with heights of more than 6m next to the motorway.

Traffic safety development – International comparison

Increasing road safety is an important goal for all countries. The national programs for the reduction of road fatalities and accidents in general, are an important input for increasing the economic efficiency of a country. Following statistics in Table 3 give an overview about the statistical development in the field of transport safety of individual countries, and show the leading fatality reduction rates in European countries such as Germany and Austria that use the systems highlighted in this paper.

Table 3. Road safety development of countries (ITF, 2014)

Road Fatalities[1]								
Recent data					Long-term trends - Average annual change			
Country	2009	2008	Evolution 2008-2009	Evolution 2000-2009[3]	2000-2009[3]	1990-1999	1980-1989	1970-1979
Argentina[4)]	7,364	7,552	-2.5%	12%	2.2%	-	-	-
Australia	1,507	1,441	4.6%	-17%	-2.1%	-3.0%	-1.7%	-0.9%
Austria	633	679	-6.8%	-35%	-4.7%	-4.0%	-2.7%	-1.8%
Belgium[2]	955	944	1.2%	-35%	-4.7%	-3.8%	-2.0%	-3.0%
Cambodia[4]	1,717	1,638	4.8%	328%	17.5%	-	-	-
Canada	2,130	2,419	-11.9%	-27%	-3.4%	-3.1%	-2.8%	1.6%
Czech Republic	901	1,076	-16.3%	-39%	-5.4%	1.3%	-1.7%	-4.0%
Denmark	303	406	-25.4%	-39%	-5.4%	-2.3%	-0.3%	-5.4%
Finland	279	344	-18.9%	-30%	-3.8%	-4.4%	3.2%	-5.2%
France	4,273	4,275	-0.05%	-48%	-6.9%	-0.7%	-1.8%	-2.1%
Germany	4,152	4,477	-7.3%	-45%	-6.4%	-3.8%	-4.7%	-3.4%
Greece[2]	1,456	1,553	-6%	-29%	-3.7%	0.4%	3.7%	3.4%
Hungary	822	996	-17.5%	-32%	-4.1%	-6.7%	3.2%	0.8%
Iceland	17	12	41.7%	-47%	-6.8%	-1.5%	1.3%	3.4%
Ireland	239	279	-14.3%	-42%	-5.9%	-1.6%	-2.2%	1.4%
Israel	314	412	-23.8%	-31%	-4.0%	1.2%	1.0%	0.8%

The following aspects can be interpreted as major influences on annual figures:

- In decade 1990-1999 more and more products made of concrete influences the market
- in year 1998 the final draft of EN1317 comes in force and substitutes existing standards and national regulations
- in decade 2000-2009 all countries of the European Union are obliged to implement EN standards especially EN1317; the new standards and regulations pushed the development of new products which as a result lead to more than 100 new products for passive traffic safety were developed in this decade
- during 2008-2009 the American Association of State Highways and Transportation Officials adapted in total the NCHRP standard of the USA – 2009 the new standard MASH comes in force

Actual Developments

Country-specific actions to improve road safety:

- European Union: part 5 of EN1317 comes in force (2008) and includes the monitoring of production of restraint systems under compliance with test conditions
- European Union: the demand of vehicle intrusion as a performance parameter of restraint systems by tenders is becoming increasingly more prominent
- Germany: Harmonisation of approval procedure for use of restraint systems is raising the availability and combination of products on long-time view – suppliers are called to offer

Conclusion

The technology highlighted here presents alternatives to many of the current ways of doing things in Australia. Whilst the alternatives are only introduced briefly, we hope this opens up the possibilities available to road designers, specifiers and authorities when seeking to make Australian roads safer.

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Predicting safe driving behavior of professional bus drivers: Validation of psychometric tests using real driving performance

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Abstract

Human factors models of driving behavior often include psychomotor abilities, cognitive abilities and personality dimensions as key human attributes associated with safe driving. The present study evaluates the effectiveness of psychometric tests of these human attributes in predicting safe and effective driving performance by experienced bus drivers.

A test battery consisting of safety critical ability and personality tests was administered to 125 professional bus drivers during routine driver training. Participants drove a passenger bus under three real time driving scenarios: 1) typical road driving (without critical incidents), 2) a "dangerous situations" hazard course (involving traffic incidents), and 3) manoeuvring buses in confined spaces. Expert driving assessors scored the performance of drivers using objective and subjective criteria for each scenario (e.g. errors, speed, traffic cones moved and situational based grading).

Regression analyses of results indicate that the full psychometric test battery could predict driver performance ($R=.62$, $p<.05$), and that different combinations of ability and personality dimensions are relevant for different safe driving scenarios. For typical road driving situations, concentration, reaction time and safety relevant aspects of personality were significantly predictive of safe driving performance. For dangerous driving situations involving traffic hazards, measures of stress tolerance and visual situation awareness were most significant. For bus driving in confined spaces, logical reasoning skills which allow the planning and execution of complex driving manoeuvres were most significant. Overall, the results demonstrate the validity and utility of targeted psychometric testing in the recruitment and training of professional drivers.

Introduction

Beyond the human misery involved, traffic crashes create large direct and indirect costs for the community in general and the public transport industry in particular. For example, for the 5 year period between 2006 - 2011, there were 144 deaths from crashes involving buses in Australia (BTRE, 2012) with an estimated human cost of $2.4 million per fatality (BTRE, 2009). While travel by public transport is generally considered safer than travel by private vehicle (e.g. Risbey, Cregan & Silva, 2010; Bus Industry Confederation submission, 2003), strategies to improve safety on public transport are still important.

Road safety studies indicate that human error is a critical factor in more than 90% of road crashes (e.g. Gelau, Gasser, & Seeck, 2012; Smiley & Brookhuis, 1987), hence many road safety initiatives involve human factors interventions, such as defensive driving and fatigue management. An area less well researched is the use of psychometric tests of abilities and personality attributes to assess the safe driving capabilities of drivers. Schuhfried, an Austrian manufacturer of psychometric tests has recently completed a study into how psychological assessments can be used to predict safe driving behaviors of professional bus drivers.

Method

Professional bus drivers (n=125) from a large public transport company undertook ability and personality tests during routine safety training. Psychometric tests were chosen following an analysis of the underpinning human abilities and personality factors associated with professional bus driving. The analysis involved the GDE matrix of driver competencies (Hatakka, Keskinen, Gregersen, Glad, & Hernetkoski, 2002), which has a hierarchical approach to categorising driver behaviors in increasingly complex driving situations. This identified a set of safety critical abilities (i.e. concentration, reaction speed, situation awareness, stress tolerance, logical reasoning) and personality traits (i.e. risk taking, self-control, sense of responsibility, emotional stability) that are important for competent bus driving. Validated computer based psychometric tests assessing each of these factors were chosen from those available through the test publisher Schuhfried (schuhfried.com.au) and these became the independent variables for the study. Table 1 lists the 6 tests used.

Table 1: Ability and Personality Tests Used

Test Name	Attributes Assessed	Test Format
Cognitrone (COG)	Concentration	Speed and accuracy in completing a simple pattern matching task
Reaction Time Test (RT)	Reaction Speed	Responsiveness to visual and auditory signals
Adaptive Tachiscopic Traffic Perception (ATAVT)	Situation Awareness	Visual orientation and perception speed when recalling features from traffic photographs
Determination test (DT)	Stress Tolerance	Hand and foot pedal responses to rapidly changing visual and auditory signals
Adaptive Matrices Test (AMT)	Logical Reasoning	Abstract reasoning test involving extrapolating and completing complex patterns
Inventory of Driving Related Personality Traits (IVPE)	Risk Taking Self-Control Sense of Responsibility Emotional Stability	Questionnaire style personality assessment

The dependent variable for this study was each participant's bus driving competency, which was assessed by expert driving instructors during three driving scenarios: 1) typical road driving (without critical incidents), 2) a "dangerous situations" hazard course (involving traffic incidents), and 3) manoeuvring buses in confined spaces. Figure 1 depicts the three driving scenarios. A GPS-based G-Force-logging device was also used during the driving scenarios to measured physical vehicle dynamics including lateral and vertical jerking, acceleration speed, and cornering forces.

1. Typical road driving

- 30-minute bus drive in real life traffic
- Standardized route involving urban areas, highways and motorway
- No safety incidents or crashes
- Roundabouts, intersections, priority situations, etc.

2. Hazard course

- A driving obstacle course involving critical driving situations
- Breakdowns, pedestrian crossings, narrow roadways, serpentines, concealed turns, reversing

3. Manoeuvring

- Time-critical manoeuvring
- Narrow roadway, bends and slalom driving, height monitoring situation, parking sideways and backwards, driving onto verge

Figure 1: Bus driving scenarios

Assessment of the dependent and independent variables were undertaken at a driver testing track in Vienna Austria in January 2015. Figure 2 overviews the study design and primary outcomes.

Study Design

- Cooperation with a private **bus company**
- **Testing** as part of a safety training course for **125** employees working as professional drivers

Psychometric Testing

- **Ability factors:** Concentration, reaction speed, situation awareness, stress tolerance, logical reasoning.
- **Personality factors:** Risk taking, self-control, sense of responsibility, emotional stability.
- **Battery length approx.** 120 minutes

Driving Capability Assessment

- Completion **of safety-related driving scenarios** in the 3 areas of:
  - Real-life road driving
  - Hazard course
  - Close Quarter Maneuvering
  - **Driving competency** scoring by a driver trainer, time taken to complete driving tasks, errors made, electronic data logs

Results and implementation

- **Ability and personality dimensions** are demonstrated to be **relevant** in different driving situations
- **Validation of a battery of tests** for use in the recruitment of professional drivers (called SAROAD)
- **Implications for using psychometric assessments** in post-incident safety investigations and targeted training

Figure 2: Bus driver study design and primary outcomes

Analysis & Results

Results from psychometric testing and driving performance were evaluated using regression analyses. Driver competency was determined through the expert driver trainer ratings and error/mistakes ratings in the 3 driving scenarios. Those ratings were aggregated into driving scenario scores and correlated with the psychometric test results. If the tests are predictive of driver competency then better performance in the driving scenarios should be associated with higher test results, which was found to be the case. In this analysis the correlation for the combined battery of tests was found to be R =.62 ($p < .05$) for the typical driving scenario. Therefore, results from the complete battery of 6 tests were able to predict around 38% of the variation in driver competency under standard driving conditions. The full test battery correlations with the hazard course scenario and manoeuvring scenarios were found to be R =.52 ($p < .05$) and R =.502 ($p < .05$) respectively, accounting for approximately 25% of the variance in driving competence in these scenarios.

The analysis also found that different attributes more strongly predicted performance for each of the 3 driving scenarios. Table 2 summarises the strongest test predictors for each driving scenario.

Table 2: Abilities and personality traits associated with different driving scenarios

	Driver Competency Assessments (driving scenarios)		
	Typical Road Driving	**Hazard Course**	**Manoeuvring**
Relevant Abilities:	Reaction speed Concentration	Situation awareness Stress tolerance	Logical reasoning
Relevant Personality Traits:	Risk taking Self-control Sense of responsibility Emotional stability	-	-
Correlation (R):	0.54	0.38	0.28
Tests Used:	COG (Concentration) RT (Reaction) IVPE (Personality) *	ATAVT (Adaptive Tachistoscopic Traffic Perception Test) * DT (Determination Test) *	AMT (Adaptive Matrices Test) *

* significant at $p < .05$

Discussion

This study has demonstrated that psychometric tests assessing ability and personality factors, can successfully predict the driving competency and safe driving performance of bus drivers. This group of 6 tests has since been combined into a commercially available test battery called Safety Assessment Road (SAROAD).

The finding that different tests can predict performance in different driving situations indicates that test results can also be used to identify specific driver competency gaps. This diagnostic approach may be useful in assessing ability deficits related to driving incidents or crashes, as well as assessing driver competencies to inform driver training needs. In summary, the findings from this study indicate that psychometric testing can be a useful tool for recruiting, assessing potential driving deficiencies and the targeted training of safe and competent bus drivers.

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Using humour in peer-education: Trials and tribulations of an action research project

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Abstract

Background. Action research projects (ARP) in which students operationalise practical approaches to specific health issues are a compulsory element of the Queensland senior Health Education subject. As part of the ARP, the first Author was consulted by the second Author and her students regarding young driver road safety issues, interventions, and intervention evaluation. The "students" then developed a humourous parade presentation and three surveys targeting youth driving distracted. **Aims.** To overview the humourous peer education project, to examine the impact of the presentation upon "participants" behaviours; and to reflect upon the difficulties and successes associated with engaging researchers, teachers, and youth (students, participants). **Method.** Seventy-six Year 11 and 12 participants (61.8% female) completed a pre-presentation survey (baseline survey); 267 participants watched the presentation and immediately completed evaluation survey one; 42 of these participants completed evaluation survey two a fortnight later. **Results.** <u>Baseline survey</u>: 60% of participants had been a passenger in a car in which the driver was texting. <u>Evaluation survey one</u>: 77% of participants reported the presentation had made them think about their actions on the road as a driver and/or passenger; 33% of participants reported the take-home message related to active behaviours such as eyes-on-the-road and phone-in-the-boot. <u>Evaluation survey two</u>: 43% of participants reported they had been a passenger of a distracted driver during the intervening period. **Discussion and Conclusions.** Translating research findings into real-world practice and policy is a challenge for all road safety researchers. Engaging with youth can also be challenging, and the school environment provides an ideal context for peer-based intervention. Researchers play a key role in translation, supporting teachers and students with limited resources.

Introduction

Secondary students and health education

Currently in Australia, primary and secondary education is a shared responsibility. That is, there is a national curriculum for children in classes from foundation (preparatory) to Year 10, whilst senior education has a state-based framework. Health Education is an authority subject approved and issued by the Queensland Curriculum and Assessment Authority (QCAA, formerly the Queensland Studies Authority (QSA)), and which contribute to the student's overall position (OP) score which is used to rank students wishing to continue with tertiary studies. Health Education is commonly offered in schools in Queensland, and in a considerable proportion of schools in the Sunshine Coast region in particular. Whilst each school is able to choose the unit focus, the unit must "engage students in the investigation of specific health issue/s" (Queensland Government (QG), 2010, p. 6). Given the pervasive overrepresentation of youth in road crashes in general, and as young drivers in particular, it is unsurprising that road safety is a recognised 'specific health issue'. For example, in Australia and New Zealand, drivers aged 18 years sustain the most injuries and fatalities in road crashes (Bradshaw et al, 2015). In Queensland, 13.9% of 2014 road crash fatalities and

18.3% of hospitalised casualties involved a driver aged 17-20 years (TMR, 2015), despite these drivers comprising 6.2% of the licensed population (TMR, 2013).

An important aspect of the Health Education syllabus is the compulsory requirement of an *action research project* (ARP) which is “process-driven and provides the opportunity for students to work through practical approaches to health issues” (QG, 2010, p. 16). An ARP has many elements such as developing the course of action, providing a statement as to the purpose, providing evidence of data collection, implementing the campaign, critically evaluating the process, and justifying recommendations, conclusions and/or modifications. ARPs are usually presented within the school environment rather than the wider community due to issues pertaining to accessibility, resources, target-audiences, timelines for implementation and assessment, and limited budgets.

QCAA recommends that health promotion projects implemented at a school level use the Health Promoting Schools (HPS) framework comprising the three key areas of curriculum, teaching and learning; school organisation, ethos and environment; and partnerships and services. It is important to address each of these components when planning or implementing school activities, programs and policies in the area of Health Education. As noted earlier, road safety is a popular Health Education topic, and based on the introduction thus far, is ideally suited to an ARP within the HPS framework. This is consistent with the recommendations of the 2006 Royal Automobile Club of Victoria’s research report such that “All school-based traffic safety activities should use the…HPS…framework as a template for action (RACV, 2006, p.39).

Caloundra State High School (CSHS) has utilised the ARP for the past four years, with road safety featuring as a topic in each of these years. Whilst the HPS framework is suited to ARPs, there is no formal guidance for educators, including those working within Senior Health Education. Some peer-reviewed literature regarding researchers exploring action research ‘on the coalface’ are available (eg., Gubac-Collins, 2007), however anecdotal evidence (TF) suggests that typically time-poor teachers do not access, nor understand the translation of, resources such as peer-reviewed journal articles and conference papers, an additional obstacle to operationalising best practice and evidence-based efforts. Thus, in 2013 CSHS Senior Health Education teacher TF approached University of the Sunshine Coast Accident Research BSP to act as a resource to inform a young driver road safety action research project for Year 11 Semester Two Health Education students.

Peer support and education

Peer support and education is a health risk model in which peers engage with peers to effect health-risk-related attitude and behaviour change. Peer education and support is popular within injury prevention and harm minimisation domains such as hepatitis C treatment amongst opioid drug users (e.g., Roose, Cockerham-Colas, Soloway, Batchelder, & Litwin, 2014), appropriate medicine use amongst senior citizens (e.g., Klein, Ritchie, Nathan, & Wutzke, 2014), and promotion of road safety amongst the community (e.g., Montero, Spencer, & Ariens, 2012). Amongst youth, peer support and education programs such as peer-led sexual health education (e.g., Chambers, Boath, & Chambers, 2002; Layzer, Rosapep, & Barr, 2014) and peer-led anti-smoking (e.g., Starkey, Ausdrey, Holliday, Moore, & Campbell, 2009) are not only popular with recipients of such programs, reductions in risky behaviours are apparent post-intervention (e.g., 22% reduction in odds of regular smoking, Starkey et al., 2009).

Within the realm of youth road safety, peer support programs predominantly comprise designated-driver programs, in which one of the occupants of the car abstains from drinking during the social event. Interventions incorporating media support (eg, radio and television advertising), such as ‘Pick-a-Skipper’ in Western Australia have been found to increase the numbers of persons to choose a designated driver before venturing to a drinking venue. Males, however, were less likely to be a designated driver, and this is particularly concerning as males engage in more risky driving behaviour (Watson & Watson, 2014). In addition, in general programs have been found to be more successful if combined with media campaigns (Boots & Midford, 1999). Some colleges in the United States implement peer support and education programs, such as the BACCHUS and GAMMA Peer Education Network in which peers are trained and then conduct injury prevention activities, including safe road use and abstaining from drink driving (Everett, Lowry, Cohen, & Dellinger, 1999).

Using humour in road safety interventions

Road safety interventions such as media campaigns have been found to reduce crashes in the general driving environment, however success usually requires accompanying police enforcement (Cameron, Haworth, Oxley, Newstead, & Le, 1993; Phillips, Ulleberg, & Vaa, 2011). It is noteworthy that media campaigns have traditionally often used shock-tactics in a fear-based approach to ‘scare’ young drivers into behaving in a less-risky way. Whilst fear may attract attention, it is unlikely to result in cognitive and behavioural changes in young drivers (Kohn, Goodstadt, Cook, Sheppard, & Chan, 1982; Lewis, Watson, & White, 2009). Research suggests that positively framing messages, and specifically including safer alternative behaviours, is more likely to result in positive behaviour change (Ramos et al., 2008; Sibley & Harre, 2009). The 2007 ‘Pinkie’ campaign in New South Wales, Australia, utilised humour in an attempt to reduce young driver speeding behaviour via a social marketing campaign linking speeding with reduced masculinity in young male drivers. The campaign was popular amongst the driving population in general and young persons in particular (Watsford, 2008), winning numerous advertising industry prizes (Clemmenger BBDO, 2009). Initial evaluations found the young driver was more likely to negatively comment on another young driver’s speeding (RMS, 2009).

Study aims

The aims of this paper are to (a) overview the humourous peer education project developed as part of the ARP, (b) summarise the road safety-related research findings, and (c) to reflect upon the difficulties and successes associated with engaging researchers, teachers, and youth.

Method

Participants

Seventy-six participants (Year 11 and 12 students, n = 47 females, 61.8%; 54% with Learner driver’s licence, 6.6% with Provisional (intermediate) driver’s licence) completed the Pre-Presentation Survey three weeks before the live-parade presentation. Two hundred and sixty-seven participants (Year 11 and 12 students, n = 124 females, 60.5% of gender-identified students) completed the paper Evaluation Survey One immediately after watching the live-parade presentation. Ninety of these participants reported they were in Year 12 (n = 58 females, 64.4%), and 121 reported they were in Year 11 (n = 66 females, 54.5%). Forty-two participants (*n* = 31 females, 73.8%; *n* = 24 in Year 11, 57.1%) who completed Evaluation Survey One also completed Evaluation Survey Two online two weeks after the live-parade presentation. It is noteworthy that, given the idiosyncrasies of the ARP, the students were not required to obtain participant consent nor to obtain Ethics approval to conduct the research. The first Author obtained Ethics approval to assist in the data analysis and interpretation of the findings (University of the Sunshine Coast Human Ethics Committee approval A/13/533). Submission of a survey was deemed to indicate consent-to-participate.

Design, Procedure, and Materials

The development of the ARP involved accessing literature, expertise, and a breadth of resources, over a number of sequential stages including (1) a class discussion to define the scope of the project, including considering young driver risk factors identified in the literature sourced by TF, such as the Fatal Five (Queensland Police, 2013); (2) general class discussion with BSP regarding young driver and young passenger risk factors, and the characteristics and efficacy of a breadth of young driver interventions (including recent Australian humour-based campaigns, such as the New South Wales' pinkie road safety campaign, http://www.advertising.nsw.gov.au/campaigns/speeding-no-one-thinks-big-you; and the Victorian rail safety 'Dumb ways to die' campaign, http://dumbwaystodie.com/); (3) class decision to focus on driver distraction and the crash risks associated with the use of mobile phones by the young driver and by their passengers, targeting every student in Years 10, 11 and 12 given the high likelihood that they would currently or imminently be young drivers, and/or young passengers of young drivers; (4) class decision that the project would incorporate a 10-minute live-parade presentation consisting of a humorous performance by students with the slogan "Keep your hands on the wheel", and surveys to gauge audience on-road behaviour and the impact of the live presentation; and (5) allocation of project tasks to small groups of students.

The live-parade presentation comprised a simulated vehicle being driven by a female driver carrying four female passengers; a mobile phone rings; a rear-seat passenger answers call and discusses driving to a party and says to the driver 'Here it is' whilst showing the party address on Google Maps on the phone; the driver is distracted a second time because she wants to use her own mobile to text her mother to advise they will be late; and the vehicle crashes into a tree on the side of the road; closing with a screening of "Blind", an anti-road trauma advertisement emphasising stopping distances (http://www.tac.vic.gov.au/road-safety/tac-campaigns/ distractions/Blind). The teacher then acted as a compere who highlighted key risks (e.g., mobile phone distraction) and steps to minimise risk (e.g., keep your eyes on the road). Finally, an Instagram pledge, based upon the Transport Accident Commission (TAC) Road Trip Forever campaign (http://www.tac.vic.gov.au/road-safety/tac-campaigns/young-drivers/road-trip-forever), asked students to pledge they would keep their hands on the wheel was advertised on a laminated business-card-sized document distributed on parade after the paper survey had been completed. The final ARP element was an 800-1000 word assignment: "*Critically evaluate the process undertaken, the effectiveness of your action plan, and suggest modifications based on evidence."*

Surveys

Three surveys using a mix of open-ended (eg, *What is one thing you will take away from this performance?*) and binary choice questions (eg, *Did you like the live performance?*) were developed by the Health Education students. The Pre-Presentation Survey was distributed via email to all Year 11 and Year 12 students three weeks before the presentation, using the online survey platform SurveyMonkey, and explored the participants' knowledge of current road safety campaigns and the Fatal Five, and experiences of speeding, changing music, and texting whilst driving. Evaluation Survey One was a paper survey completed immediately after the presentation. The survey explored participant knowledge and attitudes post-presentation, such as the perceived presentation message, if and why the presentation encouraged the participant to think about their actions on the road, and the presentation take-away message. Evaluation Survey Two was distributed via email to all Year 11 and Year 12 students two weeks after the live-parade presentation via Survey Monkey and explored participant knowledge and behaviours, such as whether the participant had travelled with a distracted driver since the presentation, and if the presentation message changed their driving/passenger habits during the preceding two weeks.

Statistical analyses

Responses were compared for gender (where gender is known; n = 205) and year level (participant age was not collected in the surveys; n = 211) using chi-square analyses with a significance level of $p < .05$. All analyses were conducted in Statistical Package for the Social Science (SPSS) version 21.

Results

Survey One: Pre-Presentation Survey

Three quarters of participants advised that they had been in a car being driven over the speed limit, and nearly 60% of participants reported they had been a passenger in a car when the driver was texting. Half of the participants selected the correct combination comprising the fatal five (not wearing a seatbelt, driving under the influence of alcohol, driving whilst fatigued, driving whilst distracted, and driving in excess of posted speed limits) from a multiple choice list of options. Forty-two percent of participants said that have never or rarely been (or seen) the driver changing the music whilst driving, 32% reported 'sometimes', 26% reporting most of the time or always engaging in this behaviour.

Evaluation Survey One

The majority of participants reported that the main message was "Don't get distracted"; with the remaining responses all pertaining to road safety and safe road use behaviours such as "Hands on the wheel". Over 90% of participants reported that the presentation was humorous, and most reported it was an appropriate length (2.3% selected "too long"). A significantly greater proportion of Year 12 participants reporting the presentation was humorous (97.2% of Year 12, 89.4% of Year 11). The innovative humorous approach undertaken by the ARP students was designed to be enjoyable for the audience participants. The majority of participants reported they 'enjoyed it' (36%) or 'really enjoyed it' (21%). Over three-quarters of participants (77%) advised the presentation has made them think about their actions on the road, including a non-significantly (p = .06) larger proportion of female participants (77.4% of females compared to 64.3% of males). Twenty-one percent of males and 8.0% of females, 9.1% of Year 11 and 17.6% of Year 12 students, were 'not convinced' by the presentation. One-fifth of participants (21%) did not contribute a takeaway message from the presentation. The combination of driving attentively and responsibly (i.e., be safe, be responsible, contemplation, pledge, don't get distracted) accounted for 39% of takeaway messages, whilst the combination of 'active' behaviours (i.e., eyes on road, no loud music, phone in boot, hands on wheel) accounted for a further 33% of takeaway messages. Interestingly there were no significant differences according to gender or year level.

Evaluation Survey Two

Nearly 43% of the participants who completed the second evaluation survey reported they had been in a car when the driver was distracted during the two-week period since viewing the presentation. Whilst there was a considerably greater proportion of males (54.5%) to females (36.7%) and Year 11 (50.0%) to Year 12 (29.4%) students who had travelled in this highly risky manner, these differences were not statistically significant (likely due to the small sample sizes). Eighty-two percent of students recalled that the safety message pertained to ensuring the driver wasn't distracted, with 88% of participants reporting they were asked to put their phone in the boot to avoid temptation. Forty-eight percent of the participants were correct in identifying the fatal five, with 35.3% of Year 12 participants were correct, compared to 54.2% of Year 11 students. Again small sample sizes appear to have prevented identification of statistically significant differences. Pleasingly 59.5% of participants reported that their driving/passenger habits had changed during the past two weeks as a result of the class message. The largest changes were apparent in female participants (45.5% of males, 66.7% of females) and Year 12 participants (54.2% of Year 11, 70.6% of Year 12). Information regarding these changes was not provided, however.

Operationalisation of the Action Research Project

A number of logistics-related considerations were noted. Given the complexities of the secondary school environment, the Authors also note that it is likely that the development of the project may proceed in a different manner and incorporate different elements and modes in different schools. (i) In general, liaising between student groups proved difficult as some groups had not put enough thought into the project and therefore the knock-on effect impacted the group writing the compere script quite considerably. Another key difficulty included late inclusion of activities (such as the pledge cards and Instagram). (ii). As part of the development of the live performance, students considered the presentation environment and supporting props. Initially students wanted to use a real car door obtained from a Wreckers yard; however no student volunteered to investigate or deliver the door to the school, therefore this option was abandoned in favour of a cardboard cut-out of a car door. The Arts department facilitated the use of paint and equipment, whilst one student donated the cardboard. (iii). Various information technology issues were identified during the development of the live performance. As a mobile phone was a major part of script, students wanted to ensure that the ring could be heard (an audio cue for audience). Students held two practice sessions using props, chairs and microphones, deciding that two microphones were needed. Accordingly a student sound technician was also required. “Blind” required the use of audiovisual equipment (television and surround sound) which was also managed by the student sound technician. (iv) As part of the HPS framework, engagement of other students not enrolled in the Year 11 Health Education class was considered vital, thus options for engaging these students were discussed. Year 10 do not attend parade on Wednesday morning, and given the students were only allowed one presentation opportunity, the ARP was tailored to Year 11 and Year 12 participants who were seated in rows of approximately 25 participants per row, roughly 16 rows deep. All participants could easily view the live performance as the audience was seated on the ground and the performers were elevated as they sat on chairs as part of the simulated car. Most participants were observed to pay attention to the presentation.

General discussion and recommendations

Surveys

The majority of students advised the live-parade presentation prompted them to think about their driving, and pleasingly two weeks after the event most students reported that the live-parade presentation message pertained to distracted driving. The low proportion of students in the two surveys (pre-presentation, post-presentation) who could correctly identify the fatal five was disappointing, particularly as the live-parade presentation included a summary of the fatal five, in addition to the pervasive and extended media regarding the fatal *outside* the school environment. Notwithstanding this unsatisfactory result, over half of the students advised that their driving or passenger habits had indeed changed since viewing the live-parade presentation, with the change reported by a larger proportion of female than males, and Year 12 than Year 11 participants. However the manner in which they changed remains unexplored at this time. In addition, whilst there was low recall of the distance driven distracted, as depicted in the 'blind' advertisement, most participants correctly recalled the advice to place their mobile phone in the car boot.

Importantly for effective road safety intervention, one-fifth of participants did not report a takeaway message from the live-parade presentation, despite completing other elements of the paper survey. The Authors are unsure at this time if this is (a) because they did not want to fill in the open response item; (b) they did not engage with the presentation; (c) they genuinely did not identify any take home message in the live-parade presentation; or (d) some other factor influencing their response that remains unidentified (e.g., insufficient time to complete the survey). Ideally there would be a 100% response rate to this item, which would suggest that the ARP had engaged with the participant and that a safe road message was taken away after all the students' efforts. Disappointingly for both future ARP development, and road safety intervention, nearly half the participants did not advise *why* they were prompted to think about their driving after viewing the presentation. It is noteworthy that nearly half of the participants who completed the final survey reported they had ridden in a car driven by a distracted driver in the two-week period since viewing the live-parade presentation. At this time the circumstances surrounding this risky behaviour are not known, however the persistence of this phenomenon despite the recent attempts of the ARP students is disappointing.

Action research project trials and tribulations

Schools have multiple roles to play in the road safety of the young driver, and in the instance of this ARP, two roles can be defined. Firstly, completing the ARP itself is likely to have contributed in some way to the improved road safety behaviour of the students themselves. Principally this is because the students were actively engaged in the road safety topic, and as such had to research the topic, emphasise the importance of the topic to a larger audience, and critically evaluate their efforts as part of school assessment over a 10-week school term. However at this time this remains unclear as there were no specific measures in this regard. Secondly, schools play a part in educating their students more generally regarding health risk behaviour, and this ARP in particular provided an avenue to not only educate through increased engagement, but also to evaluate the short-term impact of the evaluation upon participant behaviour. In general, the ARP targeted an appropriate audience as participants had either a Learner or Provisional driver's licence, and the majority had travelled in a vehicle when the driver was texting. Also in general, the presentation was an appropriate length, and participants liked the presentation because it was humorous and conveyed a message, despite an almost 50-50 split in preferences between the live-parade and the ‘blind’ presentations. Suggested improvements for the live-parade presentation primarily related to the need for ‘better acting’, which is beyond the scope of the senior health education subject.

In Australia, the implementation and evaluation of projects which support health education efforts in the high school setting is haphazard and undertaken on a state-by state and territory-by-territory basis (e.g., see Carruthers & James, 1993). Whilst there are professional development opportunities for educators, these are limited in the breadth and depth of their capacity to guide curriculum development and learning experiences in health education specifically, and possibly in senior education more broadly. As a result, educators ‘on the coal face’ of the senior learning experience are largely left to their own devices to develop, implement, evaluate and improve upon their student’s learning activities, such as in the instance of action research projects, within the various frameworks such as the HPS framework. Further, TF was particularly interested in her students developing an *engaging* project, and as such a live performance was deemed to be a suitable mode. It is noteworthy, however, that modes of delivery are another topic of concern when delivering ARP, particularly as the mode of the process driven project is left largely to the discretion of the students under the guidance of the educator. Nebulous guidance irrespective of the specific health issue, such as “implement the campaign/action research project”, and that the “instruments developed in this category may be of long- or short-term duration, may complement other investigations or may form a discrete approach to the investigation of an issue” (QG, 2010, p. 16), whilst allowing great flexibility in project scope, are contributing to difficulties with breadth and depth.

The scope of ARP merits further consideration. Anecdotally, TF is aware that panel feedback usually contains comments such as “*tasks are too broad and focus on breadth rather than depth of a health issue*”. There is, however, limited guidance on focusing on the depth of a health issue, rather than the breadth of the health issue. Whilst an exemplar of a sample assessment instrument and student responses for a health action research project are provided by QSA, the exemplar has a caveat: “the assessment instrument is not presented in a way that would allow its immediate application in a school context” (QSA, 2010, p.3). Further, the alignment between the example task and the submitted work is lacking, thus contributing to educator difficulties. For example, there are a multitude of topics within an example of body image, however even pursuing one element such as air-brushing can become unwieldy and too broad. Thus it is recommended further professional development activities address this issue, in addition to the provision of clear guidelines with greater specificity which can be readily accessed. Related to difficulties with scope, the introduction of the Instagram pledge to the current action research project proved to be an overwhelming failure, with one pledge only being made after the live-parade presentation. This was in stark contrast to the expectations of the ARP students, who had anticipated a very high uptake of this element of the project given the student’s reliance and popularity of technology including the internet, and that integration of the pledge had been based upon a conceptually-similar government-sponsored campaign.

TF is aware that other High Schools in the Sunshine Coast region are engaged in similar ARP. However, there is no coordinated or systematic sharing of concepts, trouble-shooting experiences, results, and guidance for improvements for ARP for future student cohorts. It is noteworthy also that secondary teachers are unlikely to be experts in the health risk behaviour selected for the ARP, and as such struggle to locate resources and to assist their students to use these resources more generally. Resources that are found, such as peer-reviewed literature published within the domain of young driver road safety, are written for an audience of road safety researchers, and not in plain English, further hampering efforts to translate research findings into real world practice. As such, a central repository of health-risk resources – written in plain English – could assist teachers, students and participants alike to gain the maximum benefit from such core class assignments. An external resource, such as an online repository, could also provide a source for educators not only of guidance and instructions on *how* to actually design an effective ARP, but also a site where descriptions of projects, data collected, and evaluations of projects with recommendations for future projects could be accessed freely and widely by all senior educators and their students. Coincidentally this would also encourage a broader depth and variety of assessable elements which is particularly vital within the dynamic domain of health education, thus the ever-changing topics of interest would be reflected in ever-changing ARPs.

Data collection activities, a vital aspect of any ARP, must be undertaken within the constraints of the social and financial resources available to the senior health educator and their students. Contemporary school environments are under increasing budgetary pressure which means that senior health educators are using cost saving measures including electronic survey platforms such as Survey Monkey. Unfortunately the response rates to both online surveys were very low, suggesting that the financial expenditure associated with – and increased time in processing – paper surveys may be a justifiable expense (it is noteworthy in this instance that A5-sized surveys were operationalised to reduce costs). Secondary teachers also are unlikely to be experts in questionnaire development, data collection, and intervention evaluation. There is limited guidance in survey development and questionnaire design for senior health educators, and this is particularly concerning as acquiring primary data is a core component of all assessable elements as appraised in the ‘Knowledge and understanding dimension’ and ‘Application and analysis dimension’ as part of the standards matrix in senior health education (for further information, see QG, 2010, pp. 24-25). Therefore additional guidance regarding research and evaluation more generally is recommended, and similarly can be available via an online repository freely available to all interested persons.

Conclusions

Action research projects are not only a compulsory element of the senior health education subject, they may also be an underutilised avenue to effect peer-led change in the health risk behaviour of adolescents, such as in the realm of young driver road safety more generally. This is the case despite difficulties accessing clear assistance for teachers as they and their students traverse the complex waters of developing, applying, evaluating and critically appraising the action research project. Students in Year 11 Health Education at Caloundra State High School targeted the health issue of distracted driving by young drivers, and the road-safety related development, application, and evaluation of the innovative peer-led humorous project has been summarised. Implications and recommendations for peer-led interventions within the school environment were also addressed, ranging from clear and readily accessible guidelines, to targeting males and older students in particular.

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Emerging vehicle safety technologies and their potential benefits: Discussion of expert opinions

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Abstract

The aim of this study was to consult experts from Australia and overseas about their views on emerging technologies, the likely uptake of these technologies and their potential to reduce the number of crashes or crash severity. Interviews were conducted with a cross-section of vehicle and road safety experts. The topics discussed included the most promising technologies, implementation issues, time frame, limitations, and opinions on future technologies, 20 - 30 years from now. In total, 16 interviews were conducted, with nine Australian-based experts and seven international experts. The experts' responses are discussed in the context of research literature on the technologies. The experts suggested that the most important emerging vehicle safety technologies are primary safety systems that provide increasing levels of automation. Autonomous Emergency Braking (AEB) was consistently identified as having the most potential in the near future, and this was confirmed in the literature. Early introduction of vehicle safety systems that are effective at preventing injury crashes will result in significant and cumulative financial and societal savings. This paper provides a brief overview of the more promising vehicle safety technologies, a summary of the opinions of the experts interviewed and potential mechanisms for accelerating uptake of vehicle safety technologies.

Introduction

As new light vehicle safety technologies continue to be developed and deployed through the registered fleet, a need arises to gain a better understanding of their potential impact on road trauma. A research project was undertaken by the Centre for Automotive Safety Research on behalf of The Royal Automobile Club of Victoria, to examine the impact new safety technologies are likely to have in Australia, on a time scale of about 2 to 30 years (see Searson et al., 2014). A component of the project involved consulting a number of vehicle safety experts from both Australia and overseas, about their opinions on emerging vehicle safety technologies, their uptake and their potential benefits. This paper provides a brief literature review of a number of vehicle safety technologies, discusses the method used in the expert consultation, and presents the results of the consultation with some interpretation by the present authors.

Literature review

There are several vehicle safety technologies that have the potential to reduce road trauma and a brief review of the key technologies are presented here.

Autonomous emergency braking (AEB) systems allow a vehicle to detect an obstacle in its path and, without intervention by the driver, brake as strongly as possible. These obstacles may include pedestrians and cyclists, and so AEB is a technology that has the potential to prevent injury to both vehicle occupants and vulnerable road users. Anderson et al. (2012) estimated that an optimised AEB system could reduce fatal crashes by 39% and injury crashes by 48% (including pedestrian crashes). Rosén et al. (2010) suggested a reduction of 40 - 44% in pedestrian fatalities and 27 - 33% of serious injuries dependent on the system field of view. Vehicles with an AEB system may also have other systems, such as warning of the driver, strengthening of an application of the brake made by the driver, autonomous weak braking, or autonomous emergency steering.

A distinction is often made between low speed AEB, that may be effective at reducing the number of crashes and injuries in a city environment, and high speed AEB, which may reduce impact speed in higher speed environments. As the risk of a fatal injury increases at higher impact speeds (Rosén et al., 2010) an AEB that reduces impact speed in higher speed environments may save lives, while low-speed autonomy will be a convenience to the driver and will probably have some safety benefit particularly in reducing crashes involving vulnerable road users.

Connected vehicle technologies use dedicated short-range communication devices (DSRC) to allow vehicles to connect to and communicate with each other *vehicle-to-vehicle* (V2V) and/or connect to the surrounding compatible infrastructure (*vehicle-to-infrastructure* or V2I). With V2V, equipped vehicles exchange information regarding their position, speed and other vehicle specific information, and hence any emergency information regarding potential conflicts. This is distinct from V2I technology, which allows compatible road infrastructure to send messages to nearby vehicles regarding traffic signals, speed limits, intersections, stop signs, road conditions and possibly traffic flow. To date, little safety data has been published regarding these technologies. However Doecke and Anderson (2014) estimated that V2V in combination with AEB had the potential to further reduce serious injury crashes by 14 - 18 % and fatal crashes by 7 - 12 %, dependent on AEB system type.

Interlock systems are connected to the ignition of a vehicle and are designed to prevent starting and the operation of a vehicle, based on an in-vehicle assessment system. An alcohol interlock system measures and assesses driver breath-alcohol before allowing vehicle operation to commence, with intermittent tests while driving. Similarly, seat-belt interlock system assesses vehicle seat occupancy and allows vehicle operation only after seat belts are buckled. There is much optimism about interlocks, if fully deployed. Searson and Anderson (2013) suggested that fatality rates in South Australia could be reduced by 2% and serious injuries by 7% by 2030 if seat belt interlocks were made mandatory from 2015 onwards.

Following distance warning systems monitor both distance and relative speed to other objects/road users in the vehicle’s forward travel path, and the driver is alerted if the safe following distance, relative to the vehicle’s travelling speed is breached. Adaptive cruise control systems utilise this information to maintain and regulate a vehicle’s set speed including automatic brake application in order to maintain a safe following distance. Paine et al. (2008) judged that following distance warning technology might lead to a trauma reduction of 2%, as well as estimating a 1.5% reduction for adaptive cruise control.

Lane change warning systems and blind spot detection systems can determine whether or not the driver of a vehicle is intentionally changing lanes or merging into traffic, and alerts (audible or visual) are presented if potential conflicts with other road users are detected. Similarly, lane departure warning systems monitor vehicle lane positioning and warn the driver when significant deviation is detected due to unintended lane departure. Warnings can be audible, visual and/or tactile so corrective action can be undertaken. More advanced systems may apply counter-steer to maintain vehicle lane positioning. Anderson et al. (2011) estimated fatality reductions of 7% (100 fatalities) and 4,177 non-fatal injury reductions for lane departure warning systems.

Fatigue warning systems monitor and assess a driver’s level of alertness and give warning when this is determined to have degraded beyond a threshold. This can be done by monitoring eyelid movements of a driver, monitoring and assess steering wheel movements and speed of steering movements. A report by COWI (2006) considered the effect might be a 10% reduction in crashes. Paine et al. (2008) judged that this technology might lead to a trauma reduction of 2%.

Automatic collision notification (ACN) systems detect that a collision has occurred and automatically notify emergency medical services (EMS) with a precise location of the incident, thereby optimising EMS response. Such a system has been estimated at reducing fatalities by varying amounts: 1.8%, 2.4% and 2.8% (Wu et al., 2013, Ponte et al., 2015 and Chauvel and Haviotte, 2011 respectively).

Night vision systems use forward facing infra-red sensors to enhance driver vision at night, either by projecting detected images on a secondary monitor or a heads-up display, Paine et al. (2008) judged that this technology might lead to a trauma reduction of 0.4%. Reverse visibility systems utilise a rear-mounted camera that provides visual assistance to a driver while reversing, or rear-proximity sensors (using ultrasound or radar) that detect obstructions behind a reversing vehicle and provide an audible alert varying with increasing proximity to a detected obstruction. Advanced systems have the potential to autonomously brake when obstructions are detected in a reverse manoeuvre. Little data exists on the effectiveness of such systems, however, NHTSA (2014) estimate that with full deployment of a reverse visibility system (expected by 2054) compliant with the Federal Motor Vehicle Safety Standard for Rear Visibility up to 69 lives per annum might be saved in the US.

Methods

The experts interviewed

Interviews were conducted with a wide cross-section of experts from the automotive industry and related organisations. In total 16 interviews were conducted, with nine Australian-based experts and seven international experts. Three of the experts were from the vehicle manufacturing industry, two from automotive safety technology and parts supply, two from automotive communications, two from consumer testing programs, two from government institutions, two from automotive insurance, and three from research institutions.

Content of the interview

The interviews were semi-structured, in the sense that questions were standardised but discussion about the technologies were not asked in a way that encouraged precise answers, being generally open-ended and informal in tone. The questions are given below:

1. Of the safety technologies that are being introduced into new vehicles in the next 5 to 10 years, which do you think are likely to have the greatest impact on road deaths and injuries? We are interested in both primary safety and secondary safety technologies.

   For each of the technologies identified above:

   a. How many years will it be before we start to see a measurable benefit?

   b. Are there ways of accelerating the take up of this technology? e.g. can it be retrofitted to existing vehicles?

   c. What are the major limitations of this technology and are there any dangers that it might inadvertently introduce?

   d. Are there any changes to road infrastructure that will need to take place for this technology to work?

2. What do you see as some of the impediments to the adoption (or early adoption) of new vehicle safety technologies into the fleet?

3. Looking far into the future – what safety technologies would you see being introduced in 20 to 30 years time that might have a significant effect on road deaths and injuries?

4. Are you involved with any unpublished safety technology evaluations that are currently taking place, and are you able to share any results?

5. Do you have any other thoughts that you would like to share?

Results - the experts' responses

Overview of safety technologies in 5 to 10 years

The first question was designed to elicit responses from the experts regarding safety technologies that were forthcoming in new vehicles in the short term (5 to 10 years), and were perceived to have the greatest likely impact on road deaths and injuries. The responses were wide-ranging, and there was significant variation of opinion regarding which technologies were the most important and their timeframe for introduction. Table 1 lists the twelve categories of technologies that were mentioned by more than one expert and the nine types of technologies that were identified only by a single expert as having a potential for significant impact.

Table 1. Categories of technology identified by the experts as having a potential for significant impact on road deaths and serious injuries.

Technologies mentioned more than once
Autonomous emergency braking (AEB)
Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communications
Driver drowsiness/fatigue, distraction, or failure of concentration: detection and warning/intervention
Alcohol interlocks
Adaptive/advanced cruise control
Warning/intervention (lane keeping/departure, blind spot, speed relative to speed limit, reverse collision systems)
Advanced lighting systems
Autonomous vehicles
Autonomous braking when reversing
Automatic collision notification
V2P: Vehicle-to-pedestrian communication systems
Night-vision
Technologies mentioned only once
Feedback on risky behaviours and environments
Vehicle prognostics (avoiding breakdowns in bad places)
Better awareness of road and traffic conditions
Seat belt interlocks
Advanced whiplash protection
Pedestrian airbags
Rear seat safety
Cap or hat that protects a pedestrian's head
Technologies to reduce occupants' rotational head injury

The technologies identified by the experts as having a significant road safety potential are consistent with those examined in the eIMPACT project (Assing et al., 2006) although electronic stability control (expected to have a significant road safety benefit in the eIMPACT project) was considered to be at almost full deployment in new vehicles in Australia in 2014, and hence the experts in our study no longer considered this an emerging vehicle technology. Interestingly, alcohol and seatbelt interlocks were not highlighted in the eIMPACT project, but the experts in the present study considered these technologies important.

Time frame

Time until a "measurable benefit" was referred to in the questions, and was interpreted differently by various experts. One expert stated that the benefits of safety technologies were immediate for the owner of a vehicle with that technology, another believed that market penetration of technologies such as airbags and electronic stability control might be a guide to future benefit of emerging vehicle technologies. The same expert indicated that "For society it is dependent on penetration, penetration is based on three key players: the vehicle manufacturer (they have to provide the technology), the government (need to regulate the technology or regulate the need for it) and the consumer (they can choose to buy it when it's made available by the manufacturer, or they can wait until it's a standard feature, either by manufacturer goodwill or encouraged by ANCAP or by Government regulation)".

Australian experts also acknowledged the difference in deployment of AEB between Australia and Europe, (regarding timeframe before AEB has a measurable benefit) saying "It's already filtering into the fleet. Europe has taken it up faster. ANCAP is pushing manufacturers to include it. From 2014, Euro NCAP will require AEB for a 5-star rating (essentially). ANCAP take up will be slower but AEB will soon be required for a 5-star rating." The importance of extending AEB to vehicle reversing manoeuvres, to prevent back-over collisions, was also mentioned several times by experts.

Vehicle-to-vehicle (V2V) technologies were also mentioned frequently in interviews, but since the technology is still in its infancy, respondents were generally unsure of the timeframe for the introduction of V2V and the details of how it might work. V2V was often mentioned as something "beyond a decade" away, or as something that might not be beneficial for 20-30 years. There was a higher level of optimism about V2V from Australian experts: one respondent suggested that V2V would find its way into vehicles within two years, another suggested that it might begin to appear within 7-10 years.

Accelerating the uptake

The experts highlighted a number of mechanisms for accelerating the introduction of various technologies. These included Government regulation and increased action by consumer advocacy groups (NCAP). The experts consistently identified the need for better consumer awareness about safety technologies, and support for new vehicle assessment programs that provide a way for consumers to rank vehicles based on their level of safety technology. Financial incentives were also highlighted as a potential method to accelerate the introduction of technologies. This could be achieved by comprehensive insurance premium reductions or reductions in registration fees. Insurance discounting was identified by many experts (including those in the insurance industry) as a way of encouraging greater adoption of technologies.

Some experts highlighted the importance of influencing fleet vehicle buyers and encouraging this group to require fitment of safety technologies. Smart marketing campaigns and promotion of safety technologies to consumers of vehicles were also highlighted by the experts. One expert indicated that we “can accelerate the take up of technologies by heavily promoting it to consumers, either by educating consumers about the technology or promoting vehicles that have it already, there needs to be an awareness of the technology among consumers”. A recent survey by the NRMA suggested that although Australians prioritise safety highly when purchasing a new vehicle, they have little knowledge about specific technologies (NRMA, 2014).

Technologies that can be retrofitted may achieve benefits sooner, but there was little optimism about the practicability of this. Warning or advisory systems were seen as more feasible for retrofitting, but were not seen as effective as intervention systems.

Limitations and potential negative impacts of technology

A number of the respondents indicated that despite numerous benefits of safety technologies, there are also some limitation and negative consequences. The limitations can be classified as technical, human, socio-economic and legal.

Technical limitations included the limited ranges and applicability of sensors used for AEB. It was noted that some conflict situations and vehicle speeds are beyond the capability of current sensors. Systems relying on GPS positioning (e.g., for V2V, ISA) are subject to the inherent limitations of GPS accuracy. Issues relating to reliability of safety systems were also highlighted. Some systems may be limited to certain ideal conditions (fine weather, daylight, sealed roads, no sudden impositions etc.), whereas the biggest benefits are more likely in adverse conditions.

Regarding human limitations, drowsiness, fatigue, lack of alertness, and inattention are behaviours that are complex to predict and monitor hence technologies for monitoring driver condition may be prone to failure. Warning systems also have the limitation that if there are false positive warnings, the driver may become habituated and ignore the signal, or even switch off the technology if the warnings are annoying. The human machine interface (HMI) was highlighted as an issue, as drivers must be able to understand various safety systems and then acknowledge, interpret and react correctly.

There was also concern with information overload, bombarding drivers with information, warnings and false detections that may divert driver attention from the primary task of driving. With regards to warning systems, one expert pointed to research they had undertaken “… that found people don’t always make the right response when appropriate warnings are given”. Additionally, overreliance on the various technologies or complacency was also highlighted as a potential issue. A related issue to this was ‘driver adaption’, in that people may push the boundaries of these devices once they become familiar with them (i.e. risk homeostasis). The authors of this paper would like investigate these issues in future research. Another highlighted risk was that safety systems might not work as intended. For example even with a fatigue monitoring system, drivers would still need to self-regulate.

Issues relating to liability and litigation were also highlighted, particularly for vehicle technologies that might be imperfect or not working as intended. An expert stated that “some of these technologies are imperfect and won’t be perfect for years, and liability is something that everyone wants to avoid”. Responsibility and liability was also raised as a concern, technologies are designed as ‘driver assistance systems’, hence the driver should always be responsible. Hacking of V2V and V2I systems was mentioned as a danger in addition to privacy concerns regarding wireless communications.

There may be specific opposition to technologies that attempt to control drink-driving and high speed. One expert acknowledged, “consumer resistance, especially for alcohol monitoring. It is a relatively small group who are drinking and driving. We need to target them but we do not want to inconvenience those who are doing the right thing as well.” Another expert indicated that for some technologies there may be a “Driver’s perception that it is taking control away from them”.

Infrastructure requirements

Generally it was thought that few modifications to infrastructure would be required except in the case of V2I and V2V communication, where infrastructure was highlighted as being very important. Road infrastructure systems will need to be able to broadcast information to, and receive information from vehicles within the road network [this is compared to I2V that might be broadcast only]. The experts suggested that there is a need for government commitment to communication infrastructure and that they need to regulate the communication frequencies. A recent Austroads report also suggested a frequency be reserved for future use (Austroads, 2013). One expert summarised two core issues: “Having infrastructure that produces data that can be ‘published’, this has to be made available by transport authorities. Infrastructure must be in place to broadcast suitable content”.

Some safety technologies rely upon ideal conditions, and infrastructure changes to compensate for non-ideal conditions (e.g. improved lighting, enhancing of road edges) were considered important, particularly for vehicle guidance systems such as lane keep assist and lane departure warning. Several experts highlighted the need for good delineation markings and good road contrast. Consistency and clarity of signage was also highlighted as important. Two experts indicated that traffic sign recognition systems need standard and consistent information to function correctly.

Impediments to adoption

The cost of new technologies was seen as an important barrier to their introduction. It was suggested that new technologies are often only found on higher specification or prestige/luxury models of vehicles and are not accessible to society in general. It was acknowledged however, that some safety systems in Australia are available in low cost vehicles, but often as an optional extra. One expert considered there are too many makes, models, and variants of models available in Australia, that the market in Australia is very price sensitive, and that safety features are often removed for economic reasons.

One of the impediments identified regarding V2V (and also for V2I) was the need for consistent communications protocols. This would require leadership from the road safety community and government policy. One Australian expert suggested that we might end up following the lead of the US, who are conducting large-scale trials and are moving forward with implementing V2V. A US expert confirmed that a large-scale trial in Michigan has recently been completed, and that data analysis is currently taking place. Another potential limitation discussed for V2V and V2I was the current accuracy of GPS systems in Australia, which would need to be improved in order for these systems to work effectively.

Public awareness was highlighted as an impediment to the adoption of new technologies, it was considered important to make “consumers more aware of the technologies they need in vehicles”. One expert from Japan mentioned the need for V2V to be installed in all vehicles of all sizes, including very small vehicles and very large vehicles.

Safety technologies in the longer term

The experts were asked about the technologies that they thought would be available in new vehicles on a time scale of 20 to 30 years. The technology most mentioned was autonomous driving technology (both fully and partially autonomous systems). Such autonomous driving technologies would be introduced for both convenience and safety. Some experts still considered V2V and V2I a long-term future technology, or that V2I and V2V may be a part of more holistic autonomous driving experience where different technologies complement and interact together rather than functioning independently. The experts generally expected great improvements in road safety over the next 20 to 30 years. Some responses were very optimistic, for example: cars may become “uncrashable”, there will be “effectively no people killed on the roads”, and “we can wipe out 80% of avoidable collisions”. Others were not as optimistic but still positive about the future of these technologies.

Some respondents suggested that fully autonomous driving could never be possible, as a human driver should always be ready to take control. It was also noted that there would be legal issues surrounding autonomous driving, in terms of responsibility for an accident (would it lie with the driver or the vehicle manufacturer?) and also in terms of whether, legally, a human driver needs to be in full control of a vehicle at all times. Some respondents suggested that fully autonomous driving would only be likely to occur on highways, where the traffic system is well defined. One respondent suggested that drivers would control the vehicle’s steering and the vehicle would autonomously control its speed.

A respondent noted that Volvo would soon be releasing vehicles that could autonomously steer, brake and accelerate at speeds of up to 50 km/h. Several respondents also noted recent developments by Volvo (and possibly other manufacturers) into ‘platooning’ technologies that enable several vehicles to sit very close behind a truck for a long journey, in order to save fuel.

Other points raised by the experts included:

- Narrower lanes may be feasible with autonomous vehicles and vehicle guidance technologies (this may increase road capacity).
- Car travel may diminish with increases in cheap air travel.
- Driver behaviour may be monitored and linked to insurance costs. For example, drivers that regularly drive over the speed limit may be charged higher insurance premiums.
- The whole system of vehicle ownership may change, for example through car sharing systems.
- There are some technologies that adapt to the characteristics of a person (e.g., seatbelts for the elderly or children).

Discussion

The literature suggests that there are several vehicle safety technologies that have the potential to reduce road trauma. The experts varied considerably in their opinions, but nevertheless there were some common themes. The technologies that were most commonly emphasised by the experts were AEB and V2V. AEB was envisaged as starting to become popular in new cars within a few years, and being near-universal in new cars perhaps 10 or 20 years after that. V2V was seen as a longer-term technology, though advice or warning systems might be feasible sooner.

Australian experts had high levels of optimism about AEB compared to overseas experts, who were more likely to be cautious. This is perhaps on the basis of current deployment rate differences. In Australia approximately 7% of new light vehicles were sold in 2014 with a pre-crash/collision safety system standard, with a further 11% as optional (POLK, Oct-Dec 2014) compared to Japan and Sweden where experts indicated deployment rates of around 50% of new vehicles sold.

The authors of this paper share the optimism regarding AEB and connected vehicle technologies, because even if crashes are not completely prevented, the reductions in impact speed may be sufficient to prevent death and serious injury. Moore (1970) suggested that a 1 per cent reduction in impact speed is likely to lead to a 2.5 per cent reduction in fatality risk. AEB that can shorten reaction time by 0.1 sec and decelerate a vehicle at 8 m/sec/sec will theoretically reduce impact speed by 0.8 m/sec. A collision that might have occurred at 60 km/h (16.7 m/sec) under this scenario, would have been reduced by 4.8 per cent, suggesting a 12 per cent reduction in fatality risk. Reduced impact speed is an important intermediate aim, applicable to many technologies, in the pursuit of reduction of deaths and injuries. This underscores the desirability that the technologies operate effectively at the speeds at which serious crashes occur. It will be important that new technologies operate reliably at all speeds and perform when expected to. New car assessment programs have a role to play in this.

Other technologies about which there was optimism include technologies to combat driver drowsiness, distraction, or failure of concentration, alcohol interlocks, adaptive cruise control, warnings (lane change assist, blind spot detection, ISA), advanced lighting systems, AEB when reversing, ACN, V2P (*vehicle-to-pedestrian* communication systems), and night vision. The experts did differ between themselves with many technologies being mentioned by only one person, however these technologies may be very effective for a particular subset of crashes.

No expert identified the challenges that new technology might face, given that crash rates have historically been declining. It is very likely that current declines in occupant injuries and deaths are, in large part, due to existing/prior improvements to vehicles. As the crash rates of new vehicles decline, the benefit of new technology becomes more marginal as time goes on; this may be a challenge regarding the economics of developing and installing emerging technologies.

A number of experts did highlight the fact that the average age of vehicles in Australia is quite old (greater than 10 years) and retrofitting interventional safety technologies was not considered feasible. However, no expert mentioned the potential for compatibility issues between newer vehicles with autonomous collision avoidance technologies and advanced braking systems being deployed into a registered fleet of older vehicles reliant on driver ability and fallibility.

We acknowledge a number of limitations when consulting experts about future technologies, particularly because it is difficult to make predictions about the future. An attempt was made to interview a cross section of experts, however their opinions may be biased, depending on their expertise. Our focus was Australia, and the great majority of motor vehicle deaths occur in developing countries, Additionally, most vehicle technologies deployed in Australian vehicles are available as a by-product of international requirements or needs. Hence research and development and instalment of these technologies initially is focused predominantly outside of Australia.

It is important to evaluate safety technologies in real world situations so that the expected potential safety benefits are substantiated, and evaluations such as in EuroFOT (Malta et al., 2012) have indicated that for safety technologies they investigated (most of which were mentioned by the experts in the present study) there were indeed positive benefits.

We believe that a strong policy intervention would be justifiable for an effective vehicle safety technology. Consider a technology that is 20 per cent effective at preventing deaths and injuries. For such a technology, every year of delay in its introduction will cost, over the lifetime of vehicles sold in that year, 20 per cent of the annual crash costs. Crash costs in Australia are roughly 25 billion dollars per year, and thus each year of delay in introducing such a technology will cost around five billion dollars.

Acknowledgements

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Development of Victoria's new Motorcycle Graduated Licensing System

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Abstract

VicRoads has been working with the motorcycle community and road safety experts towards implementing a new Motorcycle Graduated Licensing System (M-GLS) in accordance with a commitment in Victoria's Road Safety Action Plan 2013-2016. This followed release of a 2010 public Discussion Paper and a 2012 Parliament of Victoria Road Safety Committee Inquiry. Motorcycling is growing in popularity, yet motorcyclist fatalities have not experienced the same reductions as found for car drivers over recent years. Research indicates that inexperience is a major contributor, with learner and novice riders comprising almost one-third of Victorian motorcycle fatalities and serious injuries. Protocols for new mandatory training, off- and on-road testing for the motorcycle learner permit, a learner "check ride" and on-road testing for the licence have been developed based on review of Australian and international motorcycle licensing systems, literature on motorcycling, behaviour change theories and adult learning, observations of current rider training in Victoria and analysis of Victorian motorcyclist crash data (2003-2013). A key focus has been to extend a current emphasis on basic skills in vehicle handling to higher-order skills, including awareness, judgment and decision making. Piloting is underway and due for completion at the time of the conference. This joint presentation by the research team and VicRoads will report on the development process and pilot results. Due to the grounding of this work in best practice, this presentation will not only provide a platform to introduce the new Victorian M-GLS but provide insights and learning for other Australian and international jurisdictions.

Background

VicRoads has been working with the motorcycle community and road safety experts towards implementing a new Graduated Licensing System for motorcyclists in Victoria. Riding a motorcycle is growing in popularity. In particular, the growing number of motor scooter riders and commuters suggests that riding has become more of a mainstream activity and is not the sole domain of motorcycle enthusiasts (VicRoads, 2010).

While the road toll among car drivers, including novice drivers, has decreased over recent years, the fatalities among motorcyclists have not decreased by the same extent. Research indicates that inexperience is a major contributor to Victorian motorcycle crashes, with learner and novice riders comprising almost one-third of all motorcycle fatalities and serious injuries (VicRoads, 2010).

Graduated licensing systems worldwide have demonstrated that having a systematic process of phasing in driving privileges over time has reduced the incidences of crashes among young novice car drivers (Senserrick & Williams, 2015). The new motorcycle training and testing regime will have an emphasis on a robust process for riders to graduate through different phases as they develop their riding capabilities. These capabilities include not only basic skills in vehicle handling, but, critically, capabilities in higher-order skill areas as well.

In 2010, VicRoads released Graduated Licensing for Motorcyclists - A Discussion Paper on graduated licensing for public consultation. The submissions were used to help formulate new policy recommendations. Motorcycle licensing practices worldwide were also reviewed. VicRoads also took into account a number of recommendations from the Inquiry into Motorcycle Safety, completed by the Parliament of Victoria Road Safety Committee in 2012.

As a result of this work, the Victoria's Road Safety Action Plan 2013-2016 included a commitment to introduce a graduated licensing system for motorcyclists to help beginners develop critical riding skills under safe conditions.

The aim of this presentation is to introduce the new Motorcycle Graduated Licensing System (M-GLS) model for Victoria and the overarching framework and approach to its development

Victoria's new Motorcycle Graduated Licensing System

Stage 1 of the new M-GLS introduced revised learner and licence phase conditions in October 2014, as summarised in Figure 1.

Learner Phase	Licence Phase (restricted licence)

• ride with headlight on at all times
• wear a high visibility vest or jacket whilst riding
• if tested on an automatic motorcycle, restricted to riding an automatic motorcycle
• retaining current requirements:
    o must only ride a learner approved motorcycle
    o zero BAC
    o no pillion passenger
    o no mobile phone use
    o no towing
    o must display L plates
    o compulsory carriage of permit
	• ride with headlight on at all times
	• no mobile phone use
	• no towing
	• if tested on an automatic motorcycle, restricted to riding an automatic motorcycle
	• compulsory carriage of licence
	• retaining current requirements:
	    o must only ride a learner approved motorcycle
	    o zero BAC
	    o no pillion passenger
	The duration for the conditions increased from 1 year to 3 years

Figure 1. Victoria's M-GLS learner and licence phase conditions

Stage 2 of the M-GLS redevelops the training and testing, as summarised in Figure 2.

Approach to development of training and assessment

Development of the new M-GLS has involved extensive collaborations, consulting, and oversights in close keeping with the conference theme of Taking Action Together.

Several advisory and steering committees were established to provide oversight to the project, including a core Project Advisory Group (VicRoads, academics and motorcyclists) and a Provider Advisory Group (representatives of current Victorian rider training providers). The committees met at core stages of the project in addition to update and consultation meetings with all providers. The research protocol was approved by the Human Research Ethics Committee at The University of New South Wales.

The training, coaching and assessment activities were developed based on review of Australian and international motorcycle licensing systems, literature on motorcycling, behaviour change theories and adult learning, observations of current rider training delivery in Victoria and analysis of Victorian motorcyclist crash data from 2003 to 2013. A key focus was to extend a current emphasis on vehicle-handling in rider training and licensing to give greater prominence to development of awareness, judgment and decision making. Therefore, the Goals for Driver Education or GADGET matrix (Hatakka, Keskinen, Gregersen, Glad, & Hernetkoski, 2002), considered a best-practice framework in novice driver education, was adapted to a Goals for Rider Education framework, with essential and desirable competencies identified at each level and activities developed to address these.

The analysis of Victorian crash data revealed the top five novice crashes in Victoria as:

- loss of control – straight;
- loss of control – curve;
- intersection;
- same direction; and
- head on.

Curriculum and assessment activities were therefore developed in the context of these five key crash types.

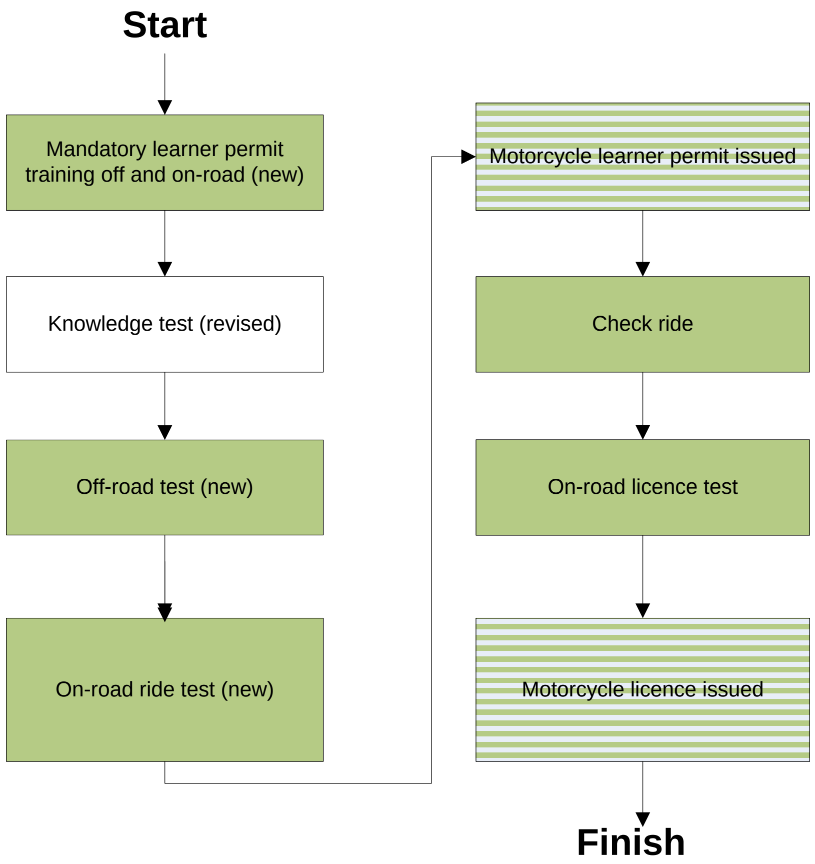

Figure 2. Victoria's new M-GLS learner and licence training and assessment

Piloting

Manuals were developed for the two-day Learner Permit Course (pre-learner curriculum and assessments), Learner Check Ride program and Licence Test, including "train-the-trainer" materials and "instructor" materials to deliver the training. Piloting was conducted with novice rider participants, trainers and instructors, as well as including experienced riders to assess whether the assessments discriminated between riders at different levels of competency (in progress for the Check Ride and Licence stages). Piloting was then followed by wide stakeholder consultation (in progress).

Conclusions

A new M-GLS has been developed for Victoria, targeting the five top novice motorcyclist crash types in the state. An important novel characteristic of the program is its comprehensive nature; including basic and higher-order skills required for safe riding. Due to the grounding of this work in best practice, this presentation not only provides a platform to introduce the new M-GLS but provides insights and learning for other Australian and international jurisdictions.

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Effect of Vehicle Roof Shape on Rollover Safety

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Abstract

Most rollover safety research considers the vehicle in an inverted (upside-down) position as the major cause of serious injuries. For example, neck injuries mostly occur when the vehicle roof strikes the ground. However, recent studies have identified that significant injuries can occur to restrained and contained occupants during other phases of the rollover event, including when the vehicle is on its side and upright. Some injurious impacts between the occupant and vehicle interior such as torso injuries are likely related to changes in their relative velocities (Δv). Such velocity changes are believed to be associated with a higher number of quarter turns during a rollover event.

This study seeks to identify the role of roof shape for Sports Utility Vehicles (SUVs) in the potential for exacerbating vehicle-occupant Δv and thus the potential risk for associated occupant injuries. Detailed computer finite element model (FEM) rollover crash analysis, determining the kinetic energy, translational velocity and roll rate changes of a simplified proxy SUV FEM vehicle that occur during a two roll event for two vehicle roof shapes (square and rounded), is presented. The vehicle's kinetic energy, translational velocity and roll rate for each considered roof shape during the rollover are compared. It is hypothesised that the rounder roof design results in a less severe change for each of these variables particularly towards the end of the rollover event, thereby reducing occupant-vehicle impact severity. This work is part of an ongoing study needing further work to confirm these findings in real-world SUV rollovers.

Introduction

Rollover fatalities and associated serious injuries continue to be a source of major concern for road safety practitioners with regard to development of effective countermeasures. Rollover crashes cause disproportionate death and serious injury[a] when compared to other crash types on Australian roads. Almost one in five road deaths (19%) occur as a result of a crash involving vehicle rollover and almost one in four deaths among occupants of a light vehicle result from a rollover crash, yet this crash type represents only 2.4% of all vehicle crashes (Grzebieta et al. 2007, Richardson 2003). In the US the disproportionate contribution of rollover to fatal crashes is even higher, with one in three fatalities resulting from a light-vehicle rollover crash and rollover crashes representing only 2% of the total vehicular crashes (NHTSA, 2013).

There has been much vehicle rollover safety research that has considered the vehicle rolling through the inverted position as the major cause of serious injuries during a rollover event. Head and neck injuries are often associated with roof crush (Rechnitzer and Lane 1994, Mattos et al., 2014). In more recent years, this research has focused on the benefits of increasing the roof Strength-to-Weight Ratio (SWR) in order to reduce serious injury risk in rollover crashes (Brumbelow et al., 2009). More recently, researchers have shown that increasing SWR alone will not result in reductions of all rollover injuries (Bambach et al., 2013; Digges and Eigen, 2003, 2007, Digges et al., 2005). Further, some of the injury distribution to body regions appears to be associated with different phases of the rollover, e.g., Bambach et al (2013) identified that torso injuries mostly occur independent of roof intrusion.

Some injuries occurring during vehicle rollover crashes are likely related to changes in the relative velocity, Δv, between the occupant's body and the vehicle interior. Such Δv could be associated with one or multiple specific quarter turns during the rollover event, and may not be limited to the vehicle's inverted position (i.e., end of the second quarter turn). Digges and Eigen (2007) found that the contact region for serious injuries was around 36% with upper interiors and 44% were with mid vehicle interiors. Bambach et al (2013) found the greatest source of thoracic injury was caused by contact with the door (nearly 60%, with no other source of contacts greater than 15%). These findings suggest that the collisions between occupant and vehicle interior are occurring at various times during the rollover event and are not limited to the inverted phases of the rollover.

Both Bambach et al (2013) and Digges et al (2013) demonstrated that increasing the amount of roll beyond four quarter turns (i.e., the vehicle passes through the upright condition as it continued to roll) has a significant increase in odds ratio for injury risk. Bambach found that "*An increase of one full vehicle roll (four quarter turns) was 8.40 times more likely to result in serious thoracic injury*." This finding has not been disaggregated, to determine if the increasing injury risk per number of quarter turns is a function of initial crash or roll severity, or the shape of the vehicle in allowing more quarter turns to occur for the same initial crash energy.

The contribution of roof shape to head and neck injury risk associated with reduced roof crush has also been subject of research (Friedman et al., 2013, Mongiardini et al., 2015), although this relationship has not been proven conclusively. This current study is concerned more with what may cause increasing numbers or severity of thoracic injuries. It is surmised that a rounder roof shape would result in smoother roll and, hence, a reduced injury risk for occupants (at least during the inverted phase of a rollover crash), when compared to a more square shaped roof structure. The rounded roof geometry will have a continuous point of contact at roughly a uniform distance from the body CG compared to the square roof geometry, for which not all contact points will be the same distance from the body CG. This effectively causes the square roofed body to rise and fall as it passes over each corner, compared to barrel type rolling of the rounded roof geometry. In particular, the shape of the vehicle roof may play a relevant role in determining the vehicle-occupant Δv during each phase of a rollover event.

This study seeks to identify the role of roof shape in determining the potential conditions for injuries to occur for vehicle occupants in a rollover. It is hypothesised that the rounder the roof design, the less severe will be the vehicle velocity changes for each of the analysed quarter turn phases of rollover, thereby reducing the potential severity of impacts between occupants and the vehicle interior. An analysis of the vehicle kinematics and the corresponding kinetic energy was carried out of a rollover event that was simulated using simplified Finite Element method (FE) vehicle models characterised by different roof shapes. Injury risk is not estimated from these simulations, but it is intended to do so in future using more detailed models.

Method

Initially, a series of simple rigid block FE proxy vehicles were created and simulations of rollovers were carried out using the LS-DYNA non-linear Finite Element Method (FEM) solver (LS-DYNA, 2012), which is suitable to simulate such crash events. The block models shown in Figure 1 generally represent the dimensions of a 2002 Ford Explorer[1]. Two variations of the model were analysed, differing in the shape of the roof. These two versions of the FE proxy vehicle were characterised by a square and a round roof, respectively. A model without wheels was initially

[1] The 2002 Ford Explorer dimensions were available from rollover crash testing conducted by TARS for another research project. Analysis by Tahan (et al., 2013) has shown the physical properties and crash performance to be comparable for 1997 through 2003 model Ford Explorer

created for each roof geometry and a subsequent evolution that included wheels was further developed, as shown in Figure 1.

It should be noted that the authors have carried out FEM analyses of both full-scale and reduced models of the Ford Explorer vehicle with and without an occupant (Mongiardini et al., 2013, 2014, 2015). However, modelling the detailed vehicle and occupants was not carried out in this study as this would have complicated the analysis with too many confounding factors, thus potentially masking the effect of roof shape on the rollover crash outcomes that were studied. Hence, proxy vehicles were simulated for the FE analysis.

The round-roof and square-roof simplified block vehicle models were assigned a mass of 1,960 kg and 1,967 kg, respectively. Also, each model had principal moments of inertia close to those of a 1998 Ford Explorer vehicle taken from the National Highway Transportation Safety Administration (NHTSA) Vehicle Inertial Parameter Measurement Database (Heydinger et al., 1998). A summary of the inertial properties of the FE models and the actual Ford Explorer is provided in Table 1.

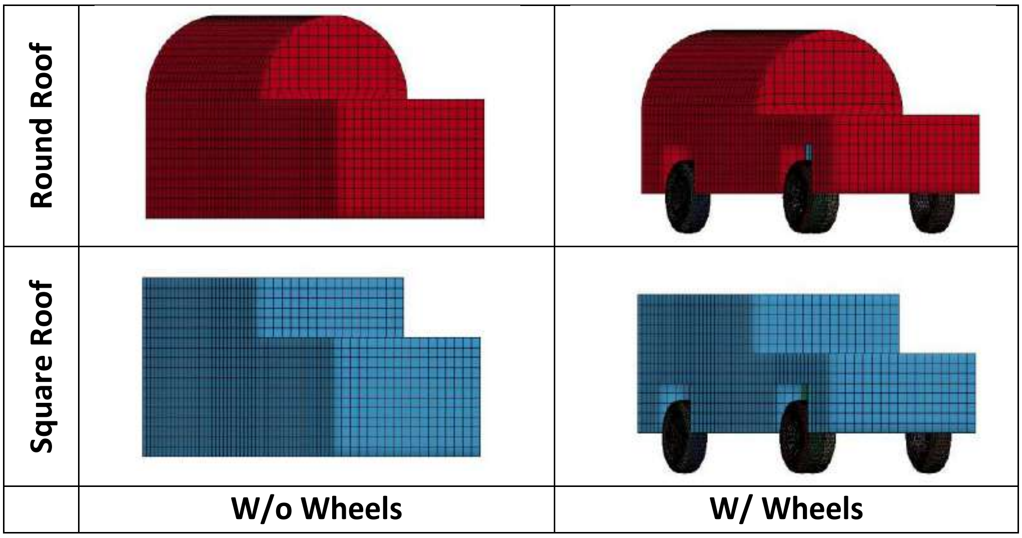


Figure 1. Round-Roof and Square-Roof block proxy vehicle models (versions with and without wheels).

Table1. Inertial Properties of FE Vehicle Models and Ford Explorer

	FE (Square Roof)	**FE (Round Roof)**	**1998 Ford Explorer**
Total Mass (kg)	1,967	1,960	2017
Moments of Inertia			
I_{Roll} (kg*mm^2)	6.45E+08	6.35E+08	7.40E+8
I_{Pitch} (kg*mm^2)	3.51E+09	3.34E+09	3.56E+9
I_{Yaw} (kg*mm^2)	3.63E+09	3.39E+09	3.68E+9

The reference diagram provided in Figure 2 indicates the roll angle, which part of the rollover event the proxy vehicle is experiencing in terms of quarter turn, and the definition of the rollover terminology used for this study.

There is a large range of initial conditions that could be considered for modelling a real-world rollover event. For the purpose of this investigation, the initial conditions imposed at the beginning of the impact with the ground were taken from a previous research conducted by the US National Crash Analysis Centre (NCAC) (Tahan et al., 2013) and the authors (Grzebieta et al., 2013a, 2013b). These conditions were from a computer simulation that has been validated against a real world crash, known to generate more than four quarter turns in a Ford Explorer rollover crash. The vehicle initial conditions were: initial roll velocity of 190 degrees/second and initial lateral velocity of 24.14 km/h (15mph); an initial downward vertical velocity of 1.4 m/s, which is equivalent to a vertical drop of 10 cm; and the first contact point with the ground was at 125 degrees of roll toward the left side of the vehicle. Initial pitch and yaw were set at zero.

Gravitational load of 9.81 m/s^2 was assigned to the model and a ground plane surface created just below the lowest point of the vehicle, which was at a roll angle of 125 degrees. The ground surface was initially assigned a coefficient of friction of 0.45, which is assumed to replicate body metal on asphalt ground surfaces (Tahan et al, 2013).

During preliminary simulations, the block models were defined as stiff structures characterised by a Young's Modulus of 10 GPa. The models were first considered as rigid blocks, not hollow structures that are deformable, and a Young's Modulus of 10 GPa was assigned as a starting point for iterative testing to develop a model that is representative of a vehicle rollover. The model progressed through rigid, elastic and elastic-plastic iterations. The rigid block preliminary models were found to be excessively stiff could not be considered as representative of a real-world vehicle rollover crash (Digges et al, 2013). To be able to compare the effects of vehicle geometry in rollover, at least one full revolution of the models were required. This was in keeping with the rollovers studied by Tahan (2013) that modelled four and eight quarter turns. These preliminary model blocks were unable to complete a full roll rotation (i.e., four quarter turns), despite the initial conditions and the model inertia properties which should have definitively provided for enough kinetic energy for the vehicle to complete at least a full roll.

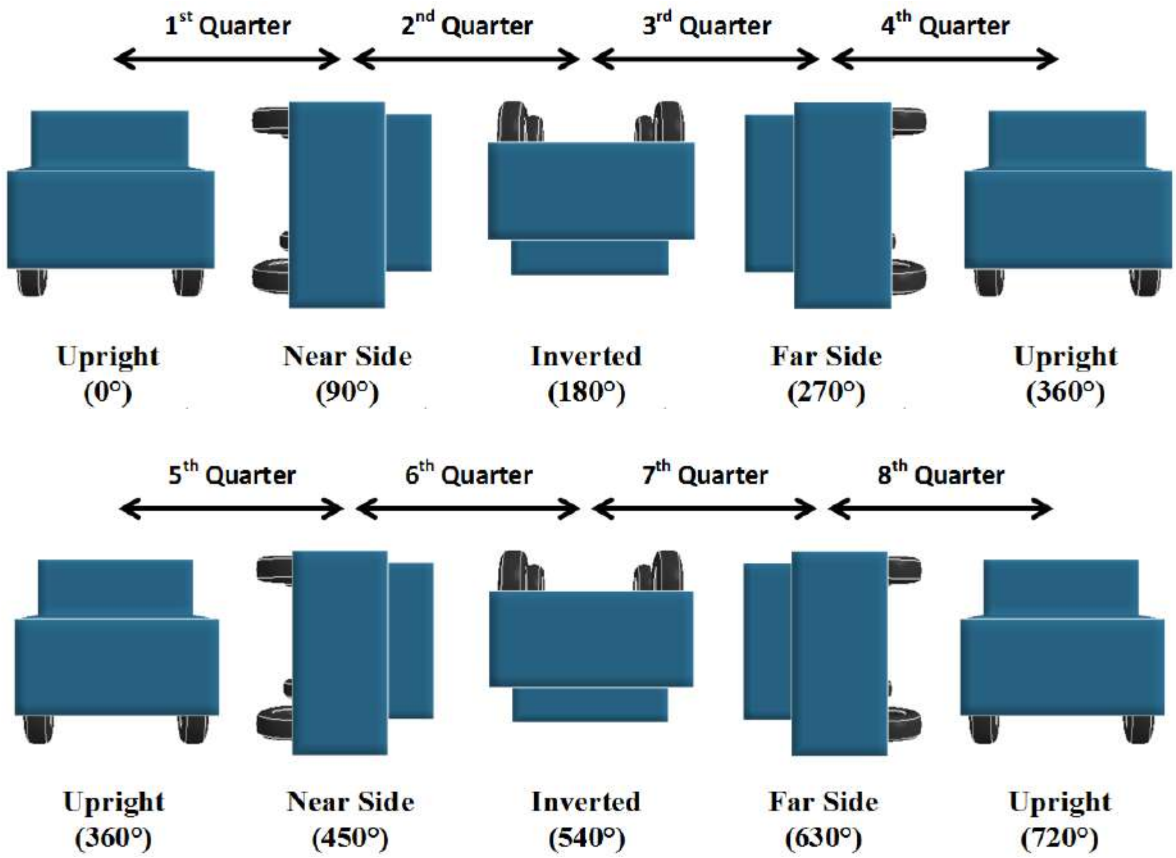


Figure 2. Angle, quarter turn and orientation viewed looking at front of vehicle.

One reason the preliminary model was unable to complete a full revolution was that when an impact occurred with the ground, the model bounced violently reacting in an elastic manner. Consequently, its roll motion reversed several times as it started rocking from front to rear about its centre of gravity.

It was found that part of the inability of this preliminary model to roll was also due to the fact that the FE proxy vehicle block would simply bounce off or skate along the road surface rather than interact with the road so that a trip initiated. In reality when a vehicle impacts and deforms a relatively soft road surface, debris can sometimes accumulate in front of the contact point that momentarily increases the coefficient of friction at that point. To address this effect of the ground deformation, the coefficient of friction of the rigid plane surface modelled to simulate the ground was increased to 0.85, to better reflect the engagement of a rolling vehicle with the roadway (not just metal sliding on asphalt). Also, to ensure a more realistic response of the model during the transition to the upright position, wheels simulating rubber tyres were added to the block models as shown in Figure 1. These changes provided some improvement to the behaviour of the FE Proxy vehicle model in terms of better replicating the kinematic behaviour of real-world and dolly launched rollover crashes observed in the literature as well as other studies and crash testing conducted by the authors and others (Digges et al., 2013, Grzebieta et al., 2013a & 2013b, Mongiardini et al., 2015). However, the model responses were still found to be unrealistic in terms of real-world vehicle rollover kinematics.

To reduce the 'tin can' bouncing effect, the model stiffness was reduced to better represent that of a real vehicle body structure. A first attempt to reduce the Young's Modulus of the modelled body block to 1 GPa and even 0.1 GPa still produced chaotic and unrepresentative kinematics. The model still bounced erratically and the square roof variant could not complete a full rotation, although with the latter value of the Young's Modulus, the simulated kinematics started to resemble more closely what is often observed in a real-world rollover crash event.

To further adjust the FE proxy vehicle to better simulate real-world vehicle deformation and produce more realistic kinematics, akin to a vehicle rolling over the roadway, plasticity was introduced into the model. This allowed the block proxy vehicle model to simulate material plastic yielding during the impacts with the ground throughout the simulated rollover event. The elastic-plastic mechanical properties behaviour assigned were:

- E = 0.1 GPa
- Yield Stress = 200 MPa
- E_{tan} = 0.01 GPa
  (Slope of a linear behaviour used to model the plastic region of the stress-strain relationship)

The vehicle's kinetic energy, translational velocity and roll rate for each considered roof shape during the rollover are compared. Each roof design is considered in terms of the severity of changes for each of these variables to gain some basic insight into what would be sudden changes in vehicle movement and thus the potential for likely occupant-vehicle impacts. The results obtained using the elastic-plastic FE proxy model are discussed in more detail in the following section.

Results

The simulated total kinetic energy (i.e., the sum of rotational and translational kinetic energies), the translational velocity and the roll rate, are shown in Figures 3 through 5, respectively. Note that the vehicle images overlapped onto the graphs show the simulated position of the proxy vehicle as viewed from the front and rolling from left to right (i.e., clockwise).

Total Kinetic Energy

For the square-roof proxy vehicle, the first significant change of energy from the initial setup condition (at 1½ quarter turns) occurs after 320 ms, when the model completed 2½ quarter turns and impacted the front left section of the bonnet with the ground. The model continued to roll clockwise, while bouncing from front to rear, such that the rear left hand-side corner impacted the ground after 560 ms. The model bounced front to rear again, while continuing its clockwise roll, impacting the lower left hand-side front corner area, after around 900 ms. The model rolled across the location of the front bumper (with its rear end raised) until the right front corner impacts the ground after about 1,280 ms, causing the vehicle to become airborne again. The vehicle continued its roll motion in free flight for nearly 500 ms until it impacted the ground across the locations of the windscreen header and the bonnet leading edge after around 1,780 ms. This impact caused a significant loss of translational velocity, as evidenced by the energy decrease from 45 kJ to 6.6 kJ, and the vehicle reversed its roll direction and then rolled counter-clockwise with much lower residual energy. In other words, using Figure 2 for orientation, the proxy vehicle rolled to an angle within the 7^{th} quarter (between 540° and 630°) after which it then rolled back anticlockwise to an angle within the 5^{th} quarter (360° to 450°). Thus, the total accumulated number of quarter turns the vehicle had undergone after 2.5 seconds are 8 quarter turns.

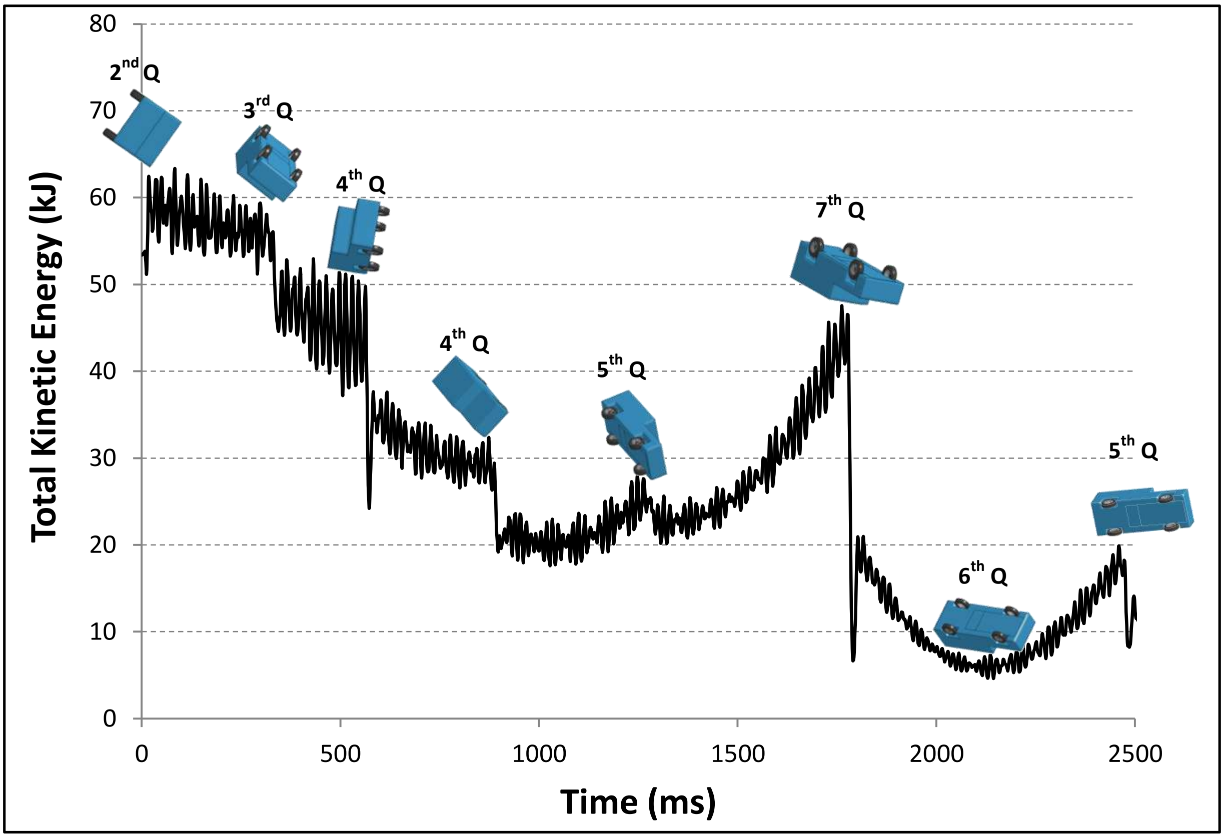
Also for the round-roof proxy vehicle the images overlapped to the graph also show the vehicle model rolling clockwise. From the initial setup condition at one and a half quarter turns, the first significant change of energy occurred after 310 ms, when the model completed two and a half quarter turns and impacted the ground at the location of the front left hand-side bonnet. The proxy vehicle continued to roll clockwise, while bouncing from front to rear, such that the rear left hand-side corner impacted the ground after 620 ms. The proxy vehicle bounced front to rear again, while continuing its clockwise roll, raising the rear end and impacting the ground with its lower left hand front corner area, after around 920 ms. The proxy vehicle became airborne as it rolled through the upright position, until its right front corner and the location equivalent to the right side of the windscreen header / A pillar impacted the ground after about 1,570 ms, with a loss of energy from 47.3 kJ to 22.4 kJ. The proxy vehicle bounced front to rear along the right side of its roof (at 5½ quarter turns), then became airborne again and continued to roll over without ground contact. The proxy vehicle impacted the ground on its left side of the roof having completed 6½ quarter turns, after about 2,500 ms. The model continued to roll and bounce, although with lower residual energy.

Translational Velocity

The translational velocity of the proxy vehicle at its centre of gravity is shown in Figure 4. The graphs show that the round-roof proxy vehicle experienced similar changes in velocity as the square -roof proxy vehicle model up until 1,700 ms. At this time, the round-roof proxy vehicle becomes airborne and rolls over its roof, without ground contact, whereas the square roof proxy vehicle impacts the ground on its bonnet and location equivalent to the roof header, causing a sudden loss of lateral velocity in the direction toward which it was rolling.

Roll Rate

Figure 5 shows the roll rate about the vehicle's longitudinal axis for each of the two simplified proxy vehicle models analysed. Comparison of the square roof versus round rates is discussed in the next section.



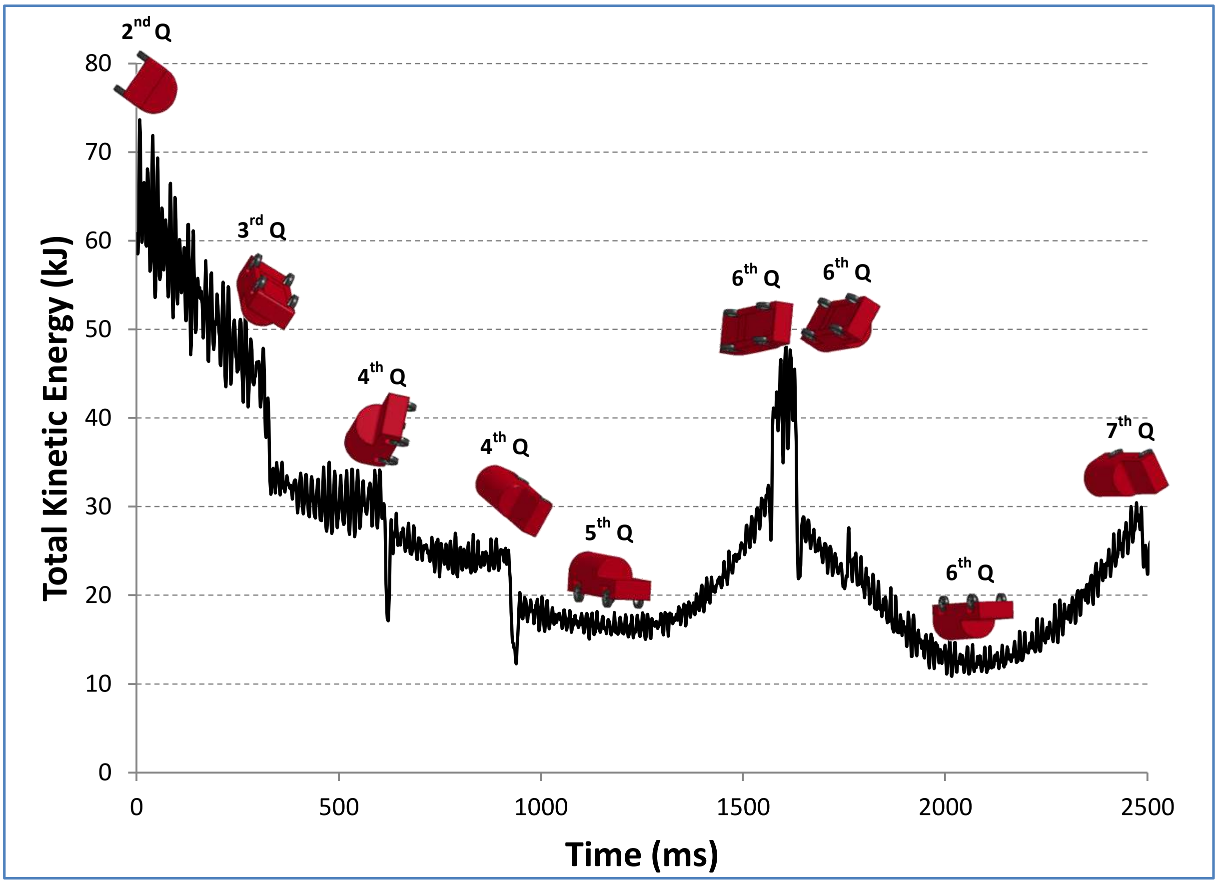
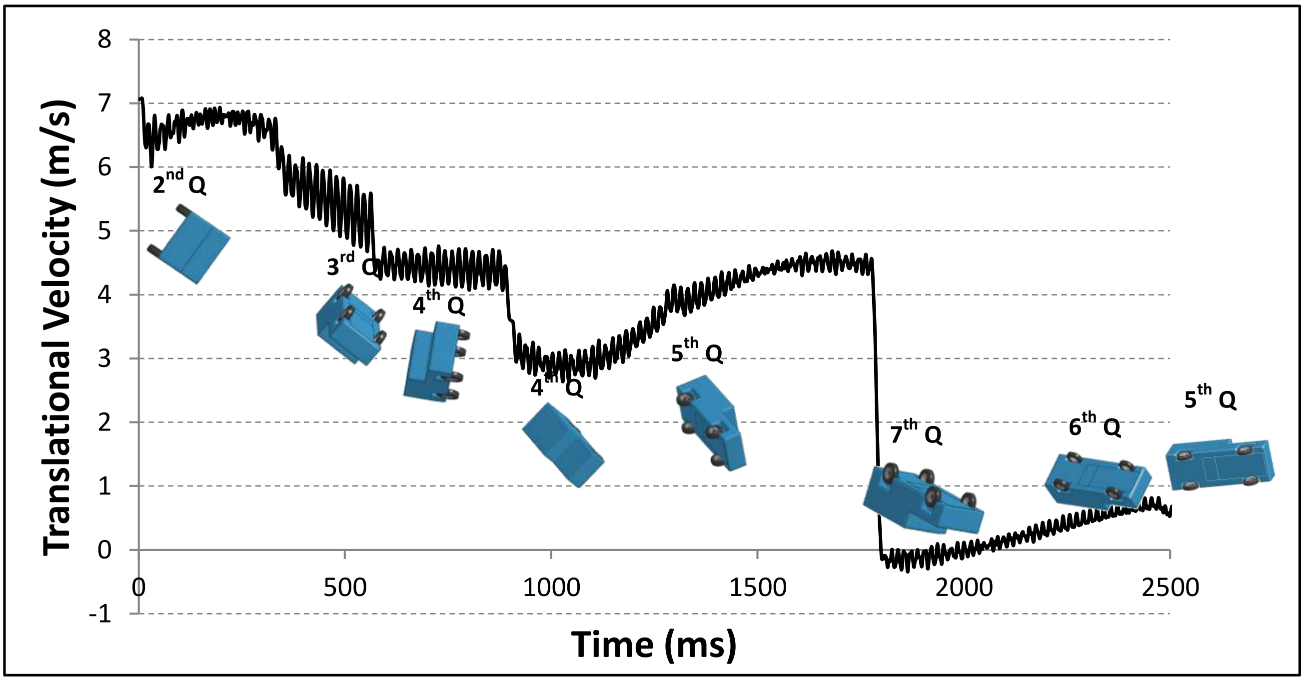


Figure 3. Total Kinetic Energy of Square Roof (top) and Round Roof (bottom) elastic-plastic Simplified proxy vehicle.



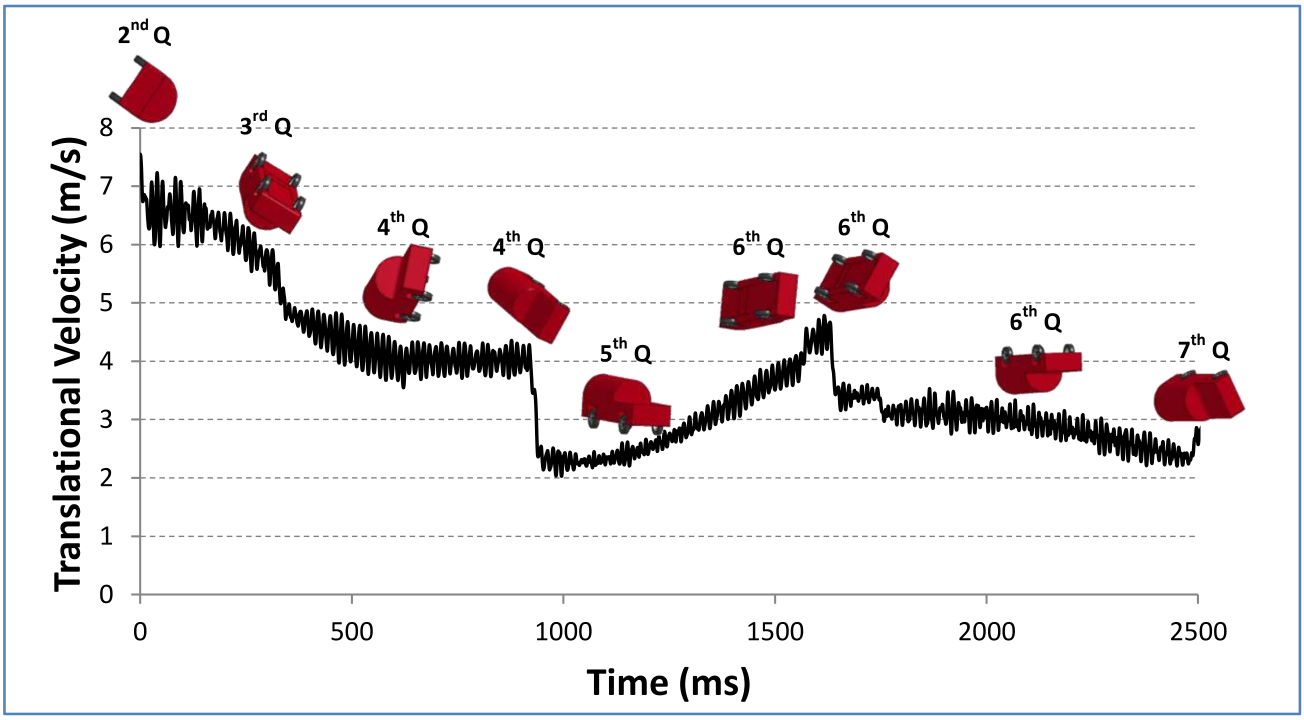
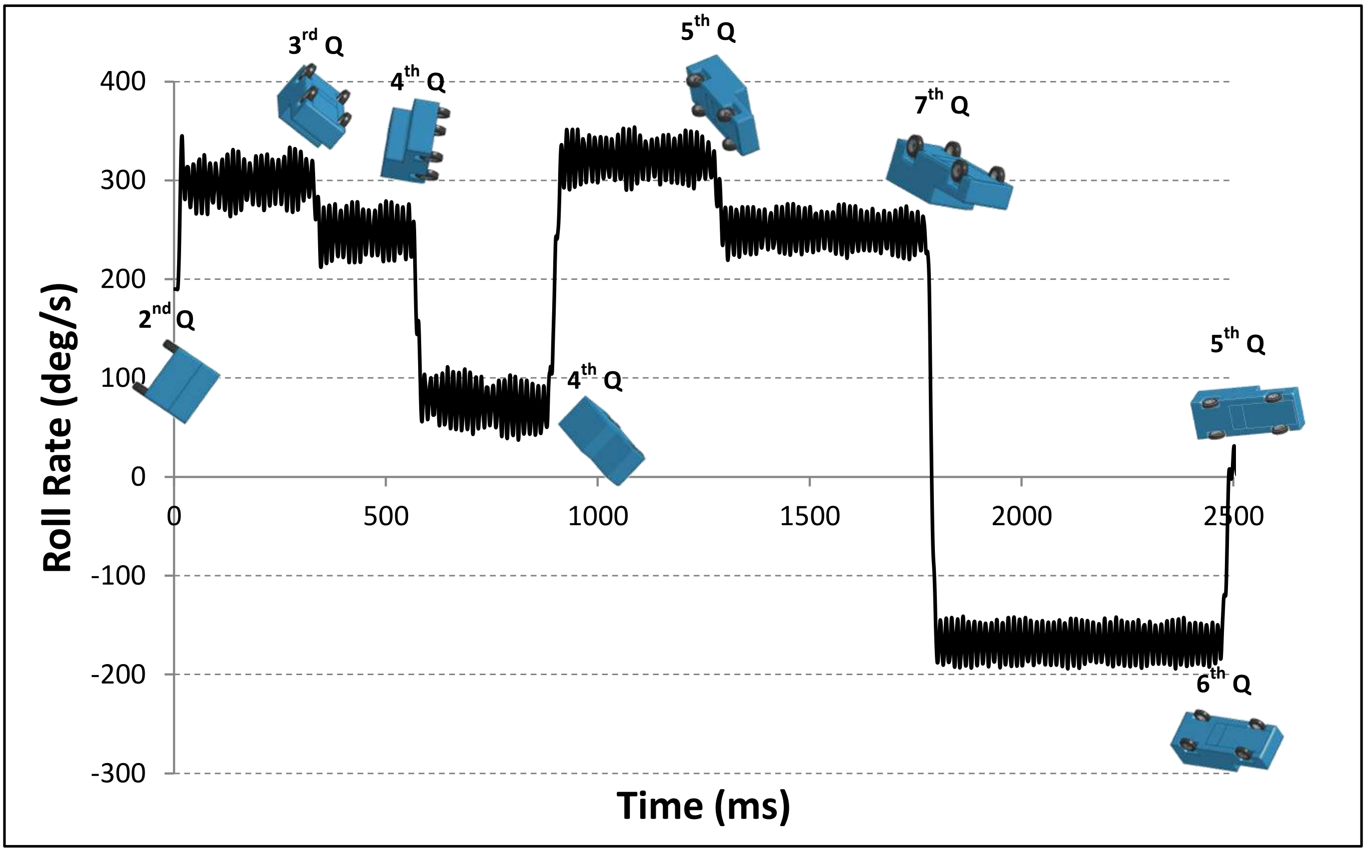


Figure 4. Translational velocity of the Square Roof (top) and Round Roof (bottom) elastic-plastic simplified proxy vehicle.



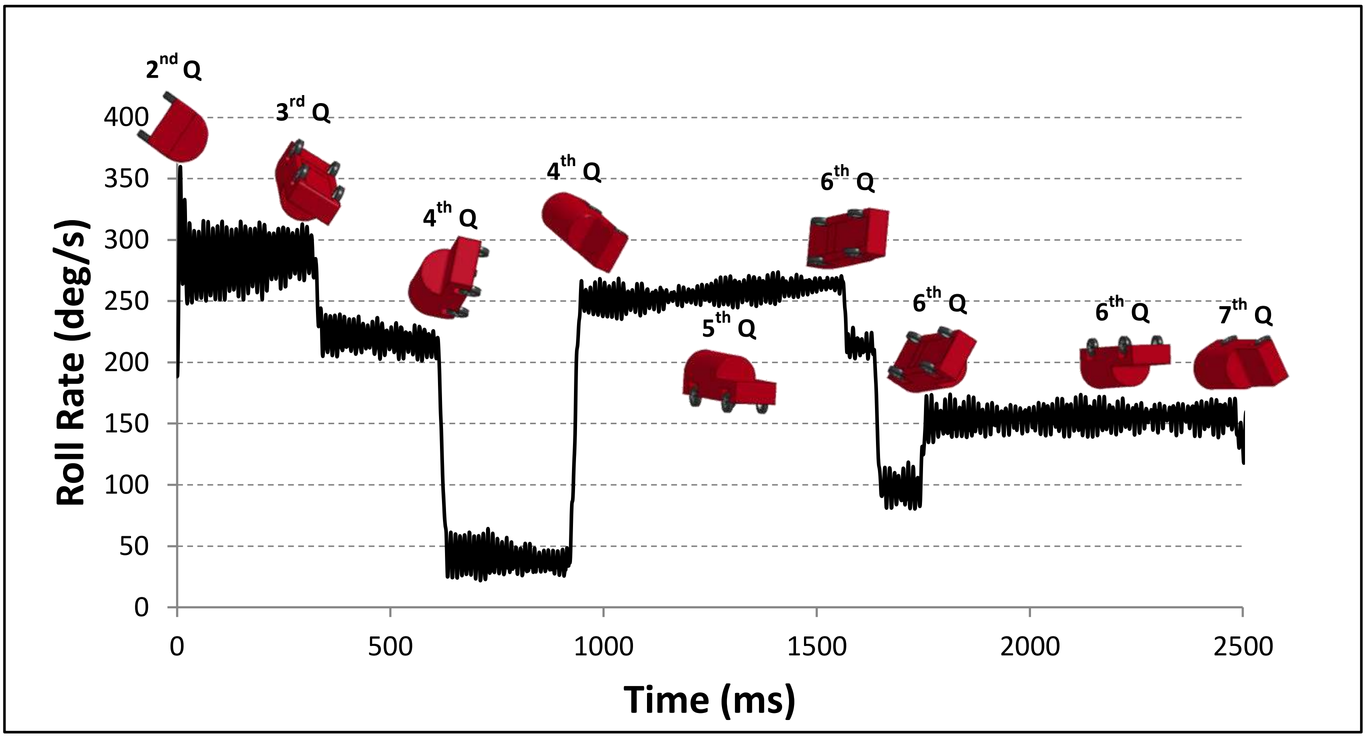


Figure 5. Roll velocity of the Square Roof (top) and Round Roof (bottom) elastic-plastic simplified proxy vehicle.

Discussion

For ease of comparison, Figure 6 shows the respective overlay of the graphs in Figures 3 to 5.

The portion of the simulation that was analysed in detail was the first 2500ms (2.5 seconds). Beyond this time, the round roof model continues to roll onto its wheels (eighth quarter turn) and then travels along on its long axis until it eventually rolls onto its side in a low energy "fall over" at about 4.5 seconds. The square roof vehicle rolls back onto its left side and rocks between the front and rear on that side until it comes to rest after nearly 6 seconds. The final stages for both models are not considered representative of real world kinematics and so were not included in the analysis.

In regards to the total kinetic energy (sum of rotational and translational kinetic energies), the round-roof proxy vehicle compared to the square-roof one appears similar up until around 1,600 ms (1.6 seconds). After that moment, the round-roof proxy vehicle had only minor impacts with the ground as it continued to roll, whereas the square-roof proxy vehicle landed inverted on its bonnet and at the location of the windscreen header rail, thus experiencing a significant phase shift and change in total energy dissipated.

When considering the translational velocity the behaviour of the two proxy vehicle models are quite similar up until around 1,720 ms (1.7 secs), with minimal differences between their velocities (and thus kinetic energy decay). The round-roof proxy vehicle model becomes airborne and rolls over its roof, without ground contact, whereas the square roof proxy vehicle model impacts the ground on its bonnet and location equivalent to the roof header, causing a sudden loss of velocity in the direction it is travelling (and rolling). Such a sudden and significant velocity change is likely to cause occupants to experience injurious impacts with vehicle internal components such as the door, seat back, centre console, roof header rail and their seat belt as well as any other item not cushioned by an airbag or padding.

In regards to the roll rate, the two proxy vehicle models are again similar for the first 1,500 ms of simulation, with minor differences associated with the slightly different points of impact around generally the same parts of the model. After about 1,760 ms, the square-roof proxy vehicle model impacts the ground in an inverted orientation, with the leading edge of the bonnet and the location equivalent to the windscreen header rail striking together. The stiffness of the model causes it to bounce off the ground, reversing its roll direction. The model rapidly goes through a change of about 428 deg/s (from around -250 deg/s to around 170 deg/s), likely resulting in significant Δv between the occupant and the vehicle body. After 1,500 ms the round roof proxy vehicle model impacts the ground surface with the front left side of the bonnet and bounces nose to tail slightly, as it continues its roll (over its roof) in the original roll direction. The round roof proxy vehicle model goes through several roll rate changes, the largest being at 1,640 ms with a roll rate change of 114 deg/s (from around -210 deg/s to around -95 deg/s) The changes to roll rate experienced by the round-roof proxy vehicle model is significantly less than that of the square-roof model.

This initial study has carried out a series of simplified FEA models to consider the effects of rounded vs square shape roofs on severe injury risk for contained occupants in rollovers involving SUVs. It has been hypothesised that more rounded roof deigns for SUVs may reduce the injury risk in rollovers.

Simplistic models of a block proxy vehicle were used, which while they do not accurately reflect the array of physical properties exhibited by a real vehicle in a rollover crash, nonetheless, these simulations provided an insight into the total energy and individual translational velocity and roll rates involved and the effect that different roof shapes can have on these towards the end of the roll event.

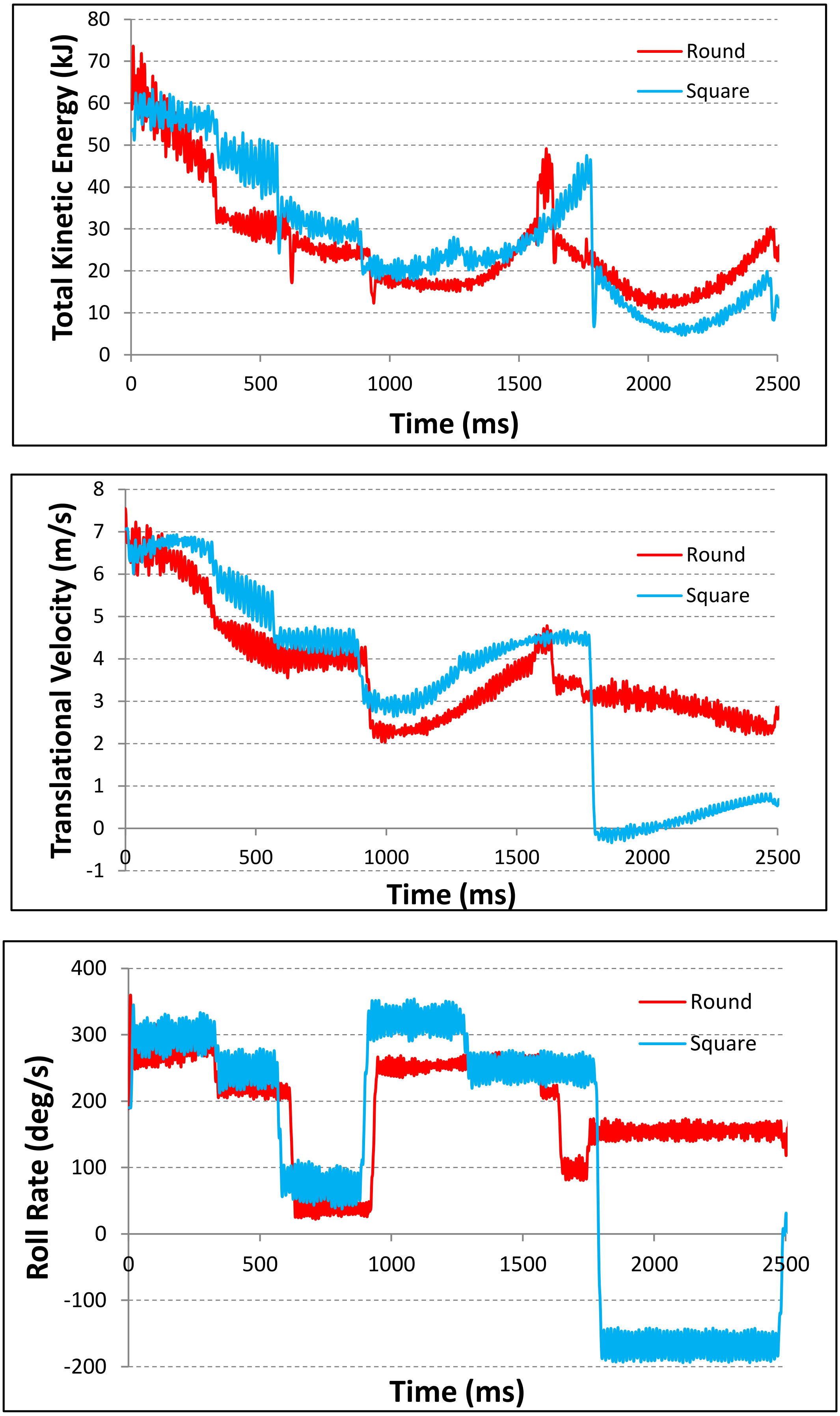


Figure 6. Overlayed graphs of total kinetic energy, translational velocity and roll rate from Figures 3 through 5 for Square Roof (blue) and Round Roof (red) elastic-plastic simplified proxy vehicles.

In these simulations, it was found that the greater changes in both translational velocity and roll rate occurred with the square-roof vehicle, and it is surmised that this would cause a greater Δv between the vehicle body and its occupants. Consequently, more internal collisions are likely to occur with the occupants, which are likely to be injurious, for an occupant within a square-roof vehicle than in a round-roof vehicle. This is consistent with the findings by Bambach et al. (2013) where the injury risk increases with larger number of accumulated quarter turns.

Simulations infer that, at least for SUVs, a round roof compared to a square-roof design may likely reduce the violence of the impacts with the ground and the magnitude of changes in both translational velocities and roll rate associated with rolling more than one full roll, i.e. through the inverted position after at least 4 quarter turns. However, more significant deformation of the vehicle glasshouse (upper) structure during the second full roll (more than 4 quarter turns) may occur, thus potentially varying this result, as also would a more realistic modelling of the stiffness for parts of the structure, including its corners.

Simulations conducted in this study considered only one set of initial conditions, which involved lateral rollover, which is the more common rollover event. Clearly there are a large range of other possible rollover crash scenarios. Simulations showed that the block proxy vehicle model impacted its front corners and was rolling over the bonnet, being biased toward a nose down pitch attitude according to the distribution of mass of the engine and transmission. The effect of ground contact with the wheels during the fourth and fifth quarter turns has not been of any note in these simulations. Further studies of alternate initial conditions are required in order to confirm whether there indeed are any differences between a vehicle with a square roof and a round roof.

Conclusions

This results of this study suggests, that for an SUV at least, roof shape does contribute to the potential conditions for injuries to occur for vehicle occupants in a rollover. For this proxy vehicle model under these initial conditions, the round roof design experienced less severe changes to translational and rotational velocity, thereby reducing the potential for severe impacts between occupants and the vehicle interior compared to the square roof geometry. It is important to note that the proxy vehicle model has not been validated against any particular vehicle or crash event and simply suggests a relationship may exist, that requires further research to confirm.

The round roof proxy vehicle model completed more quarter turns than the square roof model over the 2.5 second period analysed and for the whole event. Further work is required to determine the significance of this in terms of injury risk. The literature identifies that increasing the number of quarter turns increases injury risk significantly, but it is yet to be demonstrated if this is a consequence of increasing initial crash energy and hence the severity of those quarter turns experienced, or simply a consequence of the number of quarter turns achieved and the relationship roof shape has in regards to this outcome.

Further research is also required that would compare vehicle roof shape to injury outcomes in real-world rollover crashes. Support for this theory could be provided by a future investigation aimed at comparing injury type, severity and frequency to contained and restrained occupants during pure-rollover crashes of vehicles characterised by a more round roof compared with a square roof vehicle (assuming that both types of vehicles have similar roof strength).

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Road Safety Challenges and Opportunities in Tamil Nadu

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Abstract

Tamil Nadu is a powerhouse of India's economy, but suffers India's highest rate of fatality and double that of India as a whole. A rapid increase in wealth, population, vehicles, and traffic is occurring within a legacy road transport system that has not been designed and is not being managed to facilitate safe travel. A 2014 review to assess and make recommendations on the capacity of Government institutions to significantly improve road safety within the State has led to the development of a significant multi-year road safety program.

A number of significant capacity building projects are being implemented at a statewide level, including the establishment of an inter-departmental executive group to lead the road safety effort, and a significant investment in the Transport Department's capacity to perform the lead agency role for the State. The State is the centre of the automotive industry in India, and it is intended that a non-government forum is formed to encourage corporates, NGOs and other stakeholders to take significant actions to improve the safety of the road transport system including the safety of their own road traffic operations. A road safety demonstration project is also being developed within the Kancheepuram District, immediately south of Chennai. A range of innovative projects will be launched to complete corridor safety improvements, including working with local administrations on roadside encroachment, and a comprehensive safe systems speed management project.

Introduction

Road traffic is the number one killer of all males aged 15-29 in India, and the estimated socio-economic cost of road trauma in the country is over $US50 billion per annum. Recorded fatalities on Tamil Nadu’s roads increased by almost 60% over the last decade – from 9,570 in 2005 to 15,545 in 2013. The State ranks in the top five in terms of road accidents, fatalities and injuries, accounting for about 14% of total accidents and 12% of persons killed in road accidents in India. In 2012, Tamil Nadu had 22 fatalities per every 100,000 people, which is double the national average of 11 fatalities.

The prognosis is poor. At the core of the road trauma challenge is that a rapid increase in wealth, population, vehicles, and traffic is occurring within a legacy road transport system that has not been designed and is not being managed to facilitate safe travel. Simple analyses of fatalities by vehicle type and road type show for example that motorcycle fatalities quadrupled between 2001 and 2012 which, along with high concentrations of trauma on the National and State Highway networks, must be an urgent priority.

Management Capacity Review

The World Bank and the Government of Tamil Nadu agreed to review the road safety situation in Tamil Nadu and an executive road safety management capacity review was conducted during June and August 2014. The purpose of the review was to support development of an operational framework for road safety as part of a significant multi-year investment programme in Tamil Nadu’s road sector – the second Tamil Nadu Road Sector Program (TNRSPII).

This is intended to help establish a robust road safety management system aimed at bringing the state's challenging road safety outcomes under control. The review analysed and made recommendations on the capacity of Government institutions to significantly improve road safety within the State and has led to the development of a significant multi-year road safety program.

Challenges

A key factor in tackling the growing burden of road traffic injury worldwide is the creation of institutional capacity across a range of interlinking sectors, backed by both strong political commitment and adequate and sustainable resources. Tamil Nadu has developed a road safety policy, established a Road Safety Council, nominated the Transport Department as the lead agency, and established the function of a Road Safety Commissioner. But much more needs to be done.

The strengthening of the road safety lead agency function within the Transport Department is of prime importance. Lead agencies are central to orchestrating a jurisdiction's road safety effort, and the Transport Department's road safety management capacity needs strengthening with the establishment of a Road Safety Management Cell to perform or coordinate a series of critical road safety management functions, and support the Road Safety Commissioner.

Some further findings from the review are set out below:

a) Road safety in Tamil Nadu is currently analysed only in terms of final results such as fatalities and grievous injuries, or the disaggregation of these results, and considerable effort is required to go deeper to identify the key drivers of this trauma which can be effectively managed.
b) Greater coordination of activity is needed and improved structures need to be put in place with the establishment of a Road Safety Executive Leadership Group (RSELG) comprising the key agency leaders within Government, and a reference group to engage business and community interests in improving Tamil Nadu's road safety performance
c) There is evidence of increases in enforcement activity, but all stakeholders agree that much more needs to be done – a concerted capacity building effort is needed along with additional investment in both Police (primarily to increase detection activity) and Transport (primarily to tighten the issue of licences and permits and increase suspension/revocation actions)
d) The Government has made a significant funding allocation to initiate an infrastructure safety program, and significantly increased the size of its Road Safety Fund in recent years, and a review is now needed to establish necessary expenditure over the next five years, and to improve the quality of activity which is funded
e) Better definition of results and a supporting monitoring and evaluation programme is needed which should draw heavily in the first instance on the Road Accident Data Management System (RADMS) – this pioneering system has been recommended for use in other States and now needs additional functionality and strengthening
f) The most notable research and development initiative within Tamil Nadu is the initial iRAP surveys which was recently conducted – it highlighted major primary opportunities to address pedestrian and motorcycle safety and needs to be extended to target GOTN investment in highway safety, and evaluate the results of such investment
g) Further investment in knowledge transfer activity is needed within individual agencies and across agencies, with priorities including peer to peer exchange within India, and access to international expertise and training as appropriate.

Addressing these significant management challenges is intended to provide the basis for taking opportunities to significantly improve the safety of road users in Tamil Nadu.

Opportunities

The opportunities have been identified in terms of strengthening Statewide management systems, and addressing core safety issues at a localised District level.

Statewide Management Systems

At the strategic statewide level, the primary project support will be directed towards:

a) Implementing a comprehensive strategic support program including promotion, monitoring and evaluation, capacity building and knowledge transfer
b) Developing risk-targeted patrol plans and investment in enforcement systems targeting key behaviours for Police Department
c) Undertaking a regulatory audit and control review (including administrative sanctions) and investment in compliance systems targeting unsafe drivers and operators for the Transport Department
d) Strengthening the implementation of RADMS including its integration with the road management system and health system.

A feature of the statewide effort is the stronger set of coordination structures across government, while accountabilities for Departments are also specified. A Road Safety Executive Leadership Group (RSELG) has been formed as an inter-disciplinary institutional arrangement with very senior participation from the key line ministries/agencies engaged in road safety agenda – Transport, Police, Health, Education and Highways Departments.

The RSELG will be supported by a Road Safety Management Cell (RSMC), both with participation from the multiple stakeholder departments in the road safety agenda. Of these, RSELG is expected to oversee, guide and provide leadership to the overall road safety policies and interventions, whereas RSMC is expected to play a more operational role in terms of implementing various initiatives and serving as the secretariat to RSELG.

Significant opportunities also exist outside of government. The State is the centre of the automotive industry in India, and it is intended that a non-government forum is formed to encourage corporates, NGOs and other stakeholders to take significant actions to improve the safety of the road transport system including the safety of their own road traffic operations.

District Demonstration Project

At a more operational field level, attention has been given to the integration of local administration into road safety delivery, alongside the development of a corridor safety demonstration project led by the Highways Department. The focus of this more localised activity will be on Kancheepuram District which has the second highest population in Tamil Nadu (which has 32 Districts) and has a mix of traffic which largely represents the state's traffic.

Kancheepuram is adjacent to Chennai and has high visibility as it is one of the major centers of religion, attracting tourists from all over the state and country regularly. It is also highly industrialized – according to a recent Government of India report, the electronic software industry grows by around 50%, the auto and auto ancillary industries by about 15-20% and the leather industry by about 10% annually. The Kancheepuram District is home to several major automotive manufacturing companies such as Hyundai, Ford and Nissan.

Projects being developed within this Kancheepuram Road Safety Demonstration Project (KRSDP) are intended to:

a) Complement TNRSPII infrastructure safety investment by working with municipalities and panchayats to effectively manage roadside safety issues
b) Establish good practice speed management program including promotion, speed limit setting, signposting, enforcement and evaluation
c) Establish risk targeted patrol plans for Kancheepuram Police sub-Districts, and support

additional equipment for key offences on highways in the District
d) Establish and implement safety focussed administrative procedures targeting unsafe drivers and transport operators, including appeal and audit processes
e) Establish community health promotion campaign to support interventions, including a specific two wheeler helmet wearing promotion
f) Support quicker trauma response services and better treatment services.

A management feature of the KRSDP is the involvement of the Kancheepuram District Collector. Each District Collector holds significant administrative powers which brings a capacity to convene and oversee cross-agency delivery at a local level, and will be augmented by a local coordinating and project management structure within Kancheepuram. It will be important to take this opportunity to demonstrate stronger road safety delivery and performance at a District level.

Project delivery features in KRSDP include a specific focus on roadside encroachment and speed management. Encroachment on footpaths and roadways is the primary roadside safety issue in many low and middle income countries. In Tamil Nadu, as elsewhere in India, the issues are complex and connect with much wider socio-economic factors. It is intended that resources are made available for local administrations at a Panchayat level to develop sustainable means of improving the safety of pedestrians and cyclists who are at most risk from encroachment.

A more holistic approach to speed management is also being encouraged, within a safe systems framework. As motorisation continues apace within Kancheepuram, it will be important that some speed limits (such as the 80 km/h limit on the National Highways which run through the District) are maintained, and others are reduced to facilitate safe road environments in villages, or better managed through infrastructure treatment. More strategic advocacy and promotion regarding the seriousness of the issue and enforcement against speeding motorists is also anticipated.

Implementation

With good project management disciplines being specifically augmented with coordination and delivery mechanisms through this significant road safety program itself, it is intended to considerably strengthen the capacity of the Government institutions to deliver safer road environments for their communities. A number of operational initiatives in Kancheepuram will be linked to statewide efforts to strengthen Police enforcement systems, improve the regulatory systems and sanctions applied by the Transport Department, and invest in monitoring and evaluation activity. Processes are underway to mobilise a mix of national and international resources to support this program.

Drink and drug driving in Australian young adult users and non-users of illicit stimulants

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Abstract

Introduction: There is limited understanding of how young adults' driving behaviour varies according to long-term substance involvement. It is possible that regular users of amphetamine-type stimulants (i.e. ecstasy (MDMA) and methamphetamine) may have a greater predisposition to engage in drink/drug driving compared to non-users. We compare offence rates, and self-reported drink/drug driving rates, for stimulant users and non-users in Queensland, and examine contributing factors. **Methods:** The Natural History Study of Drug Use is a prospective longitudinal study using population screening to recruit a probabilistic sample of amphetamine-type stimulant users and non-users aged 19-23 years. At the 4 ½ year follow-up, consent was obtained to extract data from participants' Queensland driver records (ATS users: n=217, non-users: n=135). Prediction models were developed of offence rates in stimulant users controlling for factors such as aggression and delinquency. **Results:** Stimulant users were more likely than non-users to have had a drink-driving offence (8.7% vs. 0.8%, $p < 0.001$). Further, about 26% of ATS users and 14% of non-users self-reported driving under the influence of alcohol during the last 12 months. Among stimulant users, drink-driving was independently associated with last month high-volume alcohol consumption (Incident Rate Ratio (IRR): 5.70, 95% CI: 2.24-14.52), depression (IRR: 1.28, 95% CI: 1.07-1.52), low income (IRR: 3.57, 95% CI: 1.12-11.38), and male gender (IRR: 5.40, 95% CI: 2.05-14.21). **Conclusions:** Amphetamine-type stimulant use is associated with increased long-term risk of drink-driving, due to a number of behavioural and social factors. Inter-sectoral approaches which target long-term behaviours may reduce offending rates.

Introduction

Young adults are a high-risk segment of the population for dangerous driving, but it has been observed that the level of risk may vary considerably in relation to specific factors (Bingham, Shope, & Zhu, 2008; Scott-Parker, Watson, King, & Hyde, 2013). One major area of concern with regard to young adult drivers is the high rate of offences for driving under the influence of alcohol or other substances. However, despite the link between substance use and crashes, there is limited research examining factors which may influence young adults' decisions to drive while intoxicated. The available research suggests there could be an association between stimulant intoxication and driving under the influence of alcohol (Kinner, George, Johnston, Dunn, & Degenhardt, 2012; Matthews et al., 2009). One possibility, which remains untested, is that stimulant users may have a greater predisposition to engage in 'drink-driving' or 'drug-driving' compared to other young adults.

The present study compares offence rates for drink- and drug-driving, and self-reported rates of these behaviours, in young adult users and non-users of amphetamine-type stimulants (ATS; i.e. ecstasy or methamphetamine). The factors which may contribute to these offence rates are also examined.

Methods

Study design

The Natural History Study of Drug Use is a prospective longitudinal study which used population screening to recruit a probabilistic sample of amphetamine-type stimulant users and non-users aged 19-23 years. The sampling methodology is described in detail elsewhere (Smirnov, Kemp, Wells, Legosz, & Najman, 2014).

At the 4 ½ year follow-up, consent was obtained to extract data from participants' driver records held with the Queensland Department of Transport and Main Roads. In total, 352 participants consented, comprising 217 ATS group participants (61.6% of the total ATS group sample; 79.2% of the ATS group participants who completed an interview for the 5th wave) and 135 comparison group participants (66.2% of the total comparison group sample; 79.9% of the comparison group participants who completed an interview for the 5th wave). For the present study we used retrospective data extracts for the 5 years preceding the commencement of the 4 ½ year follow-up in September 2013.

Data were collected at 5 time intervals. Participants were interviewed face-to-face at baseline, 12 months and 54 months (i.e. 4 ½ years), and surveyed via the Internet at 6 and 30 months. There was little variation in drug use disclosure across data collection modes.

Measures

The frequency and quantity of recent (last month) alcohol and other drug use were measured at each data collection interval. Alcohol dependence, according to DSM-IV criteria, was assessed using the World Mental Health Survey Initiative version of the World Health Organization's Composite International Diagnostic Interview (WMH-CIDI; Haro et al., 2006). The WMH-CIDI was also used to assess lifetime occurrence of conduct disorder. Anxiety and depression were evaluated using the Hospital Anxiety Depression Scale (Bjelland, Dahl, Haug, & Neckelmann, 2002). We used the Physical Aggression Scale of the Buss-Perry Aggression Questionnaire to measure participants' aggressive traits (i.e. predisposition toward physical aggression; Buss & Perry, 1992). Functional impairment attributable to alcohol use was determined by a cut-off of 9 (90th percentile) on the Sheehan Disability Scale (Leon, Olfson, Portera, Farber, & Sheehan, 1997), and functional impairment attributed to illicit drug use was determined using a cut-off of 8 (90th percentile) on this scale.

Data analysis

Driving behaviour and background characteristics were compared for stimulant users and non-users using Pearson's chi-square. A prediction model of drink driving in the stimulant-using group was developed using Poisson regression for binomial data. The outcome was the presence or otherwise of any drink-driving offences during the 4 ½ years of the study. Predictors were related to substance use, psychological health and impairment. We controlled for sex, age and income. Adjustment was made for all variables in the full model.

Results

Stimulant users were more likely than non-users to have had a drink-driving offence (8.7% vs. 0.8%, $p < 0.001$). Further, about 26% of ATS users and 14% of non-users self-reported driving under the influence of alcohol during the last 12 months (χ^2=6.9, $p < 0.01$). No drug driving offences were recorded for participants in either group. However, 23% of ATS users compared to 3% of non-users self-reported driving under the influence of illicit drugs in the last 12 months (χ^2=24.3, p < 0.001).

Among stimulant users, having one or more drink-driving offences was independently associated with last month high-volume alcohol consumption (Incident Rate Ratio (IRR): 5.70, 95% CI: 2.24-14.52), depression (IRR: 1.28, 95% CI: 1.07-1.52), low income (IRR: 3.57, 95% CI: 1.12-11.38), and male gender (IRR: 5.40, 95% CI: 2.05-14.21). There was a marginal non-significant (p < 0.10) association between regular ecstasy use for the 4 ½ year duration of the study and having a drink-driving offence (IRR: 2.10, 95% CI: 0.92-4.81). Higher levels of anxiety were associated with a reduced likelihood of drink-driving (IRR: 0.82, 95% CI: 0.71-0.94).

Discussion

Our findings indicate that amphetamine-type stimulant use in young adults is associated with increased long-term risk of drink-driving offences. This is the first population-based study to compare rates of substance-impaired driving in young adult stimulant users and non-users. Previous research has indicated that amphetamines are the most common illicit substance detected among substance-impaired drivers on Australian roads (Chu et al., 2012; Davey, Armstrong, & Martin, 2014). However, the present study indicates that involvement in stimulant use is also linked with driving under the influence of alcohol. Moreover, the rates of self-reported drink-driving in this study suggest that offence rates represent only a fraction of problem driving behaviour in this group.

It appears that stimulant intoxication itself plays only a minor role in the relationship between stimulant use and drink-driving. The factors strongly associated with drink driving in this group included high-level recent alcohol consumption and male gender. Australian research, predominantly involving convenience samples of stimulant users, indicates that stimulant users tend to consume alcohol at risky levels (Kinner et al., 2012; Matthews et al., 2009). It may be this tendency which, above all else, results in the greatest harm. Importantly, the association between recent alcohol consumption and drink-driving was independent of alcohol dependence, psychological problems, and substance-related functional impairment.

We did, however, find a robust association between the severity of depressive symptoms and drink-driving in stimulant users. The occurrence of depressive disorders in adolescence and early adulthood has been associated with the subsequent use of stimulants, especially ecstasy, perhaps as a form of self-medication (Huizink, Ferdinand, van der Ende, & Verhulst, 2006; Smirnov et al., 2013). Depression has also been previously linked with an increased likelihood of drink-driving (Karjalainen, Lintonen, Joukamaa, & Lillsunde, 2013; Lapham, Baca, McMillan, & Lapidus, 2006). It is possible that the association observed in the present study reflects a level of susceptibility in depressed young adults for both stimulant use and drink-driving behaviour.

Young adults who use amphetamine-type stimulants are an important target group for driving interventions, especially with consideration of the relative popularity of illicit stimulant use in this age group. The risk profile of this group may provide a useful framework for the design of interventions.

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Building community capacity for road safety – are we doing it?

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[a,b] WA Local Government Association's RoadWise Program

Abstract

Capacity building is a familiar term. But what does it mean in a particular context, and can it be measured? This challenge was faced by the WA Local Government Association in exploring more inclusive methods of evaluating the RoadWise Program, with the aim of better reflecting the role of community road safety in the safe system framework.

Following extensive research and consultation, members of the RoadWise community road safety network were invited to participate in a survey which examined the following five key capacity building domains:

- Participation and community ownership;
- Opportunities for leadership;
- Community structures – with a focus on the health and functioning of RoadWise Committees;
- Access to resources for effective road safety activity; and
- Strengthened individual skills.

The results of the survey provided benchmarks, in each domain, for the RoadWise Program along with opportunities to address any gaps in delivery. Overall, the findings revealed a healthy, functioning and enthusiastic road safety network. Members of the network firmly believe they can make a difference, utilising the tools and programs offered for road safety action at a local level.

This process has helped redefine the activity of the RoadWise Program and value the role of community capacity building. It has given capacity building shape as a framework for future planning and delivery.

Background

The Western Australian Local Government Association's (WALGA) RoadWise Program works with Local Governments, community groups, private businesses and individuals to support the implementation of Towards Zero, the road safety strategy for Western Australia 2008-2020. The Program aims to achieve this by supporting local road safety committees, providing access to resources and training, and increasing road safety skills and knowledge, which all contribute to building the capacity of the network to make an effective contribution to improving road safety in Western Australia. The RoadWise Program receives funding through the Road Trauma Trust Account and the State Government Funds to Local Roads Agreement.

The RoadWise Program supports the road safety network across eleven regions, encompassing metropolitan, regional and remote areas of Western Australia. A Regional Road Safety Advisor is based in each of these regions, with the exception of the Pilbara and Gascoyne regions which are serviced, in addition to the Metropolitan South region, by a Senior Road Safety Consultant based in Perth. Project staff provide additional support through research and the development of new resources. The Program also includes the coordination of the Type 1 child car restraint fitting service, which involves the training of new Type 1 fitters and the provision of information for both Type 1 fitters and the general public regarding the correct use of child car restraints.

Community road safety programs such as RoadWise are recognised as playing an important role in generating the community support, partnerships and engagement in road safety that is integral to achieving a safe road transport system. However it is difficult to assess the effectiveness of such programs due to the challenges associated with small population sizes, relatively low numbers of crashes in individual communities, and the difficulty in separating the effects of local activities from broader campaigns or projects (Cairney, 2009).

Traditional evaluation efforts, which have focussed primarily on delivery and processes, do not provide a complete picture of the contribution of community road safety programs in the safe system. Evaluations of other broad scale community based injury prevention programs have found that a narrow view of success (for example, using only the criteria of reduction in hospitalised injuries) did not account for other broader measures of success, such as developing partnerships or increased community capacity to address safety issues (Nilson, Ekman, Ekman, Ryen, & Lindqvist, 2007).

Currently the RoadWise Program reports on a range of program delivery results to meet the requirements of funding received from the State Government. However this reporting regime does not provide a ‘big picture’ view of the impact of the program, which is central to driving future development.

Why community capacity building?

A brief review of relevant literature was undertaken to explore how similar community based programs have been evaluated, and to identify alternative means of defining the work done by the program and the network.

Laverack (2007) refers to a continuum of community based concepts, ranging from community readiness (a state of community preparedness to engage in a series of stages and partnership with an outside agent to implement a program), to community empowerment (a process by which communities gain control over the decisions and resources that influence their lives). Along this continuum, community capacity building provides the best fit with the aims of the RoadWise Program.

Community capacity building can be considered as the combined influence of a community’s commitment, resources and skills, that enables people to work together to make decisions and take action towards a positive future (Gibbon, Labonte, & Laverack, 2002). The benefits to the community of working in a capacity building approach include better reach of the target population, improved use of resources, increased levels of local participation, engagement and commitment to health action (Liberato, Brimblecombe, Ritchie, Ferguson, & Coveney, 2011).

The literature indicates that a number of different domains have been used to describe the characteristics of community capacity building and to enable the assessment of levels of capacity. Liberato et al (2011) undertook a review of capacity building domains which had been developed or utilised by other authors. The review sought to describe the attributes of each domain, and develop a set of agreed broad domain areas which could serve as a foundation for other practitioners working in this area. The authors reassembled the information to form nine domains of capacity building:

- Learning opportunities and skills development;
- Resource mobilisation;

- Partnerships/linkages/networking;
- Leadership;
- Participatory decision making;
- Assets-based approach;
- Sense of community;
- Communication; and
- Development pathway.

Six sub-domains were also identified, which were shared vision and clear goals, community needs assessment, process and outcome monitoring, sustainability, commitment to action, and dissemination.

The domain areas identified by the authors provide a guide to considering the assessment of capacity building, with the expectation that sub-components of the domains can and should be adapted and modified to suit the context and purpose of particular projects. Subsequently, the domains were reviewed to ensure they were applicable to the context of the RoadWise Program, and consolidated into the following five domains:

- Participation and community ownership;
- Opportunities for leadership;
- Community structures – with a focus on the health and functioning of RoadWise Committees;
- Access to resources for effective road safety activity; and
- The facilitation of skills and knowledge development within the network.

Method

A study of the RoadWise network was proposed to further explore the concept of community capacity building, and its potential implications for future planning and development.

The goals of the study were:

1. To identify the capacity within the network to deliver effective road safety activities and initiatives,
2. To identify opportunities for WALGA's RoadWise Program to develop and deliver future capacity building within the network, and
3. To enable WALGA's RoadWise Program to more effectively engage with our network and stakeholders.

In 2013, Research Solutions were appointed to undertake the study on WALGA's behalf. Given the geographical diversity of the network, an online survey was determined to be the most appropriate approach. To inform the development of the survey, one focus group was held in the metropolitan area, along with thirteen in depth phone interviews with members of the road safety network (eight from regional/remote areas, five from the metropolitan area).

The survey was distributed using the Local Government and community road safety network database that is maintained by the RoadWise Program. The database includes the contact details of approximately 2500 RoadWise Committee members, Type 1 restraint fitters, Local Government staff and Elected Members with an involvement with road safety, and other individuals and organisations who have been involved with the RoadWise Program in some way (for example, applied for a road safety grant). An email was sent by the RoadWise Program to all contacts on the database, informing them about the purpose of the survey, and that an email with a link to the questionnaire would be sent to them by Research Solutions in the near future. As well as making people aware of the survey in advance, this initial step also provided an opportunity to 'clean' the database by investigating or removing any emails which bounced back. The survey was emailed to a final sample of 1920 individuals.

To maximise responses, a survey reminder email was sent approximately 7-10 days following the initial survey invitation. A series of telephone reminder calls were also made following the 3 week survey administration period, and provided the opportunity for a potential respondent to be re-sent the online survey or to complete the questionnaire over the phone.

Results

The survey returned a sample of 384 respondents, representing a response rate of approximately 20%.

The survey explored each of the five community capacity domains, with a series of questions in each part of the survey designed to examine each concept in detail.

Participation and community ownership

This domain explored the active involvement of people in the activities and decisions of the road safety network, along with the commitment of individuals to working together towards a shared road safety vision.

Individuals who responded to the survey (n=384) came from all regions in WA, and represented the full range of membership categories including Local Government officers and elected members, community members, State Government agency employees, Type 1 child car restraint fitters, and the private sector. Almost half of respondents (49%) had been involved with the road safety network for between 2 and 10 years, while an additional 17% had been involved for more than 10 years. On average, respondents contributed an average of 9 paid hours and 3 unpaid or volunteer hours per month to RoadWise network activities, including implementing road safety initiatives, attending road safety meetings, providing technical advice and educating target groups.

Respondents were asked what motivated their initial involvement in the RoadWise network (more than one response was allowed). For a majority (69%) of respondents, being involved with RoadWise was a part of their employment, while other major motivators included being passionate about road safety (44%) and a desire to make the community a safer place to live in (38%). This indicates that for many members of the network, their participation goes beyond a sense of obligation as part of their job and extends to a sense of personal purpose.

Survey respondents reported a strong need for a coordinated approach at a state level (83% agree/strongly agree), along with placing a high level of importance on the effectiveness of local initiatives (74%) and the empowerment of local communities (70%). Two thirds (66%) of respondents felt that by being a part of the RoadWise network, they were making a contribution towards the vision of Towards Zero. However it is interesting to note that only around half of respondents (53%) felt that their efforts were valued at a local level, and less than a third (28%) felt that they were valued at a state level.

Leadership

The survey explored the domain of leadership, particularly in terms of where leadership comes from within the network, and whether individuals considered themselves to be leaders in local road safety. The results, while not overwhelmingly strong, were nonetheless encouraging. More than a third (38%) of respondents considered themselves to have developed leadership qualities as a result of their involvement with the network, and just under half (45%) reporting that strong road safety leaders exist in their community. There was some feeling however that additional leadership and direction could be provided by RoadWise (36%), along with more support from Local Government (30%).

Community structures

RoadWise Committees (and other road safety groups) form a framework for generating local road safety activity, and provide an opportunity to bring people together for a common purpose. Respondents who had indicated that they were a member of a RoadWise Committee or group (n=135) answered a series of questions exploring the 'health' and functioning of such group.

More than half (58%) of respondents were either satisfied or very satisfied with how their particular group operates, which high levels of satisfaction reported for functional tasks such as record keeping (81%) and meeting conduct (78%). The level of leadership (64%), diversity (61%), respect (80%) and cooperation (74%) were also high. Levels of satisfaction were lower for more strategic activities such as advocacy (53%), sourcing funding (37%) and attracting local volunteers (18%).

Access to resources

The ability of the community both to mobilise resources from within and to negotiate resources from beyond itself is an important factor in its ability to achieve success. For the RoadWise Program, the effectiveness of local road safety activity is reliant on the ability of the network to access appropriate resources.

Almost two thirds (62%) of respondents reported that they needed more road safety resources and materials to assist them in spreading the road safety message. The same number (62%) also felt that it would be beneficial to have stronger links to other RoadWise or road safety activities and programs happening in other parts of the state. Just under half (48%) of network members reported difficulties in attracting local volunteers to assist with their road safety activities and programs.

Strengthened individual skills

Individual skill development is an important element of community capacity building, with the level of contribution to the network increasing as individuals develop new skills and expertise. The survey provided an opportunity to explore how well the RoadWise Program had facilitated opportunities to develop and apply new knowledge and skills.

The results showed that for 72% of respondents, being part of the RoadWise network had opened up new opportunities for them as an individual. Sixty percent of respondents also reported that being part of the network enabled them to learn know things that helped in other parts of their lives. More than half (59%) said that their involvement in the network has led to an increase in knowledge and understanding of road safety.

Smaller numbers of respondents reported that they had been able to develop and apply new road safety skills, with 19% stating that they had gained new skills through professional development opportunities arising from their involvement with the network.

Future intentions of the network

At the conclusion of the survey, respondents were asked to indicate if they anticipated staying involved with the RoadWise road safety network, with the vast majority (92%) reporting that they did intend to stay involved in the future.

Respondents were also asked to note the one most important thing that WALGA's RoadWise program could so to assist them as an individual or their committee/group to address road safety issues in the future. Responses to this question were diverse, but were summarised as relating to:

- Additional funding or improved access to funding
- The introduction of new road safety campaigns
- Additional engagement between RoadWise committee/groups across the state to facilitate sharing of ideas
- An extended role for Local Government and RoadWise Regional Road Safety Advisors, and
- Additional advocacy for road safety at a State Government level.

These issues are broadly reflective of the results in other parts of the survey.

Discussion

The key findings of the survey are:

1. Membership of the road safety network is driven by employment and being interested and passionate about making a contribution to the overall vision of zero deaths and serious injuries on the WA road network. Aligned with personal motivators, members of the network are committed to the cause and aware of the importance of local involvement and actions. They do feel that they can make a difference. However there is a need to address the lack of value that is felt by members of the network at both a local and state level.

2. On average, members of the network devote nine paid hours and three volunteer hours to the RoadWise road safety network each month, performing a wide range of activities including implementing road safety initiatives, attending meetings, providing technical advice, educating target groups, and providing support for road safety events. With two thirds of respondents reporting that they needed more resources to assist in the delivery of these activities, more investigation is required to determine the additional tools and resources that are required.

3. Network members strongly believe in the value of community empowerment and the effectiveness of local initiatives, linked with state-level coordination. This suggests that the model of generating road safety activity through a local RoadWise Committee structure is an appropriate one, and is providing a means of interpreting Towards Zero for local communities.

4. There is significant scope for the RoadWise Program to provide support for network members to increase and apply road safety skills and knowledge through professional development and networking opportunities.

5. The community structures associated with the network are perceived to be sound and appropriate, with individual RoadWise committees/groups also perceived to be performing well. However there is an opportunity for the RoadWise Program to provide additional strategic guidance to enhance the functioning of such groups.

6. The overall health of the network is strong, with the vast majority intending to stay involved in the future. This is particularly encouraging given the range of interests and causes that compete for the time and energy of individuals and organisations.

Overall, the feedback from the network paints a clear picture of a committed and passionate group of people who, through their involvement with the RoadWise Program, feel that they are making a real contribution to reducing deaths and serious injuries in their communities. The network is the greatest strength of the RoadWise Program, and there is a clear need to continue to provide support, resources, recognition and encouragement to the network to enable the continued generation of local level activity in support of Towards Zero.

Does this mean that the RoadWise Program is building capacity? As this is a first step in a significant change of thinking, it is still a difficult question to answer. Capacity is not something that can be assigned a number or percentage to ascertain success or failure. The literature suggests that an appropriate method of assessing the overall success or otherwise of a program whose aim is building capacity, is to use a process of self-reflection, assessment and ranking by those involved in delivering the program. Program staff assign a rating to each area or theme, which are then visually represented utilising a 'spider web' approach (Gibbon, Labonte, & Laverack, 2002) (Bush, Dower, & Mutch, 2002). Such a process would provide an overall assessment of how the program is progressing towards the goal of building community capacity, along with a benchmark for the future. Repeating the survey will also provide the necessary feedback from the network, and will enable a comparison of data in each of the domains. These two steps will be undertaken by the RoadWise Program in the future.

This research represented a significant step for the RoadWise Program in the way it considers and values the way in which it operates. The process of identifying community capacity building as the best fit with the goals of the program, and then clarifying and defining the relevant domains, has in some ways been just as important as the findings of the survey itself. It had led to a significant change of thinking within the program, which is reflected in the restructure of the Program's action plan to reflect the five capacity building domains. Understanding what community capacity building means and how it is relevant to the RoadWise Program has provided a strong basis for developing the Program in the future.

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Implementing best practice principles in the delivery of a Learner Driver Mentor Program in rural Queensland: a case study report

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Abstract

Learner Driver Mentor Programs (LDMPs) assist disadvantaged learner drivers to gain supervised on-road driving experience by providing access to vehicles and volunteer mentors. In the absence of existing research investigating the implementation of Best Practice principles in LDMPs, this case study examines successful program operation in the context of a rural town setting. The study is based on an existing Best Practice model for LDMPs, and triangulation of data from a mentor focus group (n = 7), interviews with program stakeholders (n = 9), and an in-depth interview with the site-based program development officer. The data presented is based upon selected findings of the broader evaluation study. Preliminary findings regarding driving session management, support of mentors and mentees, and building and maintaining relationships with program stakeholders, are discussed. Key findings relate to the importance of relationships in engagement with the program and collaborating across sectors to achieve a range of positive outcomes for learners. The findings highlight the need for the program to be relevant and responsive to the requirements of the population and the context in which it is operating.

Introduction

Young novice drivers have a higher crash risk compared with older and more experienced drivers (Ferguson, Teoh, & McCartt, 2007). The higher risk has been attributed to underdeveloped risk perception, driving inexperience (Keating, 2007), and propensity to engage in risky driving behaviour and underestimate their crash risk (Ferguson, 2003; Mayhew, 2003). Young drivers aged 15-24 years are overrepresented in road crashes worldwide (BITRE, 2013). Despite recent improvements in crash fatality rates in Australia for this age group, road crash fatalities remain around 30% higher than older age groups (BITRE, 2013).

Greater supervised driving practice during the learner period has been associated with reduced crash involvement during unsupervised driving (Gregersen, Berg, Engström, Nolén, Nyberg, & Rimmö, 2000). This knowledge underpins the learner licence component of Graduated Driver Licensing (GDL) programs, which is a countermeasure designed to reduce exposure to known risk factors while providing an opportunity to obtain appropriate driving skills and experience over time and under supervision. Queensland currently enforces a GDL scheme. The associated Queensland Learner Licence requirements and Learner Driver restrictions are listed in Table 1.

Table 1. Queensland Learner Licence requirements and Learner Driver restrictions

Learner licence requirements	**Learner driver restrictions**
Minimum age 16 years	Must display L plates on front and back of vehicle
Pass a written road rules test	Must not use mobile phones
Must be held for 12 months minimum before attempting probationary licence test	Must carry licence at all times
Practical driving assessment	Zero alcohol and illicit drugs limit
	Drivers under 25 years must complete 100 hours of supervised driving experience, including 10 hours of night driving, and hours must be verified by the supervising driver in a logbook. Penalties apply for falsifying log books.
	Must drive under the supervision of an open licence driver, who has held their open licence for a minimum of 1 year
	No passenger can use mobile phone on loudspeaker function
	Maximum 4 demerit points
	BAC restrictions for supervising driver

Of note is that all learner drivers under the age of 25 years must obtain 100 hours of supervised on-road driving experience, of which 10 hours must be night-time driving, and all hours must be certified in a log book. Research indicates that licensing system requirements for supervised practice being recorded in a log book can result in a greater amount of supervised driving hours actually being completed by learners (Bates, Watson, & King, 2010). While there are potential safety benefits associated with increasing the amount of supervised driving that learners undertake during the learner phase, there are also potential barriers, particularly for socially disadvantaged groups, in meeting the licensing requirements. Barriers often include access to financial resources (limited ability to pay for professional lessons, or expenses such as fuel costs), access to a suitable vehicle and driving supervisor, and low literacy (Environmental Land Heritage, 2011).

Learner Driver Mentor Programs and the 'Braking the Cycle' program

In recognition of the difficulty of some groups in meeting the licensing requirements, Learner Driver Mentor Programs (LDMPs) have been designed to assist learners to obtain supervised driving hours. The "Braking the Cycle" (BTC) intervention is an LDMP that is designed to provide disadvantaged youth with the opportunity to complete the driving time requirements through coordinated access to program-provided vehicles and volunteer mentor/supervisors. BTC operates from urban and rural PCYC locations with the support of Queensland Police Service. It is a multi-stakeholder intervention and is funded by short-term grants from various stakeholders. BTC has the following objectives:

1. Assist young persons to accomplish the 100 mandatory log book driving hours to achieve their licence
2. Source driving mentors though community organisations that will provide positive role models to young people and immigrant populations
3. Increase equity of opportunity for all young persons to obtain core life and employment skills

4. Provide assistance, education and networks for L Plate drivers to support transition into P plates

The program site and learner participants

The case study focusses on the delivery of the BTC program in a single rural Queensland town location. To preserve the anonymity of research participants, the town in which the research was conducted cannot be identified. At this site, the program is coordinated by a minority group community member, with a pool of 20 mentors available to support the program, which includes one minority group mentor (female) who had completed the BTC program as a learner. At the time of data collection, the program site operated two program vehicles, and delivered on average 63 hours of supervised driving, and 1.7 licences, per month.

The program site is based within the Western Downs region which according to the Australian Bureau of Statistics (ABS) census data has a population of approximately 31,590 (ABS, 2011) and an economy that is largely based upon mining (the largest contributor to Gross Regional Product in 2012/13, at 21.5%), agriculture, forestry and fishing (13.6%), and construction (11.2%) (WDRC, 2014). As the fifth fastest growing region in Australia, the economy has benefited from resource-driven economic growth; however, a recent slowing of the local economy due to 'a premature end to the mining boom' reportedly (according to local media and perceptions of stakeholders interviewed) has negatively impacted upon local employment, housing markets and business sustainability ("Town and Out, 2015).

At the time of the last population census, the town in which the program is situated had a population of 11,016 persons, with approximately 14% aged 15-24 years, falling within the young driver category (ABS, 2011). Approximately 6% of the town population, and approximately 7.5% of the 15-24 age group, is reported as Aboriginal and Torres Strait Islander (ABS, 2011). The region is characterised by a somewhat transient population (WDRC, 2014). The number of Learner to Provisional licence upgrades for the region in 2011 was 607, however it should be noted that population transiency may impact upon this figure (TMR Data Analysis Unit, 2011).

Preliminary qualitative data from program staff indicates that, consistent with existing literature (Environmental Land Heritage, 2011), barriers for the program participants at the site in meeting the licensing requirements include lack of finances and social support, and access to an appropriate vehicle and/or supervisor. There is limited public transport, provided via buses and taxis services, available in the community.

Research aim

To date, there is little research to evaluate the effectiveness of LDMPs in Australia (Soole et al. 2014). In the absence of existing research investigating the implementation of Best Practice principles in LDMPs (Soole et al. 2014), this case study examines successful program operation, as conducted in a rural town setting. The data presented is based upon selected findings of the broader evaluation study. The comprehensive Best Practice Guidelines identify eight essential requirements for LDMPs in the operations phase. Upon review of the data obtained from staff and stakeholder interviews, it was found that the topics raised by the program coordinator, mentors, and stakeholders pertained to three of the Best Practice principles for program operation, outlined below:

1. *Ensure the driving sessions are well-managed*: This principle centres on the management of the vehicle, including storage, access, and appropriate use, driving session booking

management, and the relationship between program staff, mentors and mentees regarding driving sessions.

2. *Provide ongoing support for mentors and mentees*: This principle relates to providing mentors with appropriate training, and providing mentees with life skills and assistance to help with any social issues that they are experiencing.

3. *Maintain communication with key stakeholders*: This principle refers to ongoing communication between the program site coordinator and stakeholders, including regular program progress meetings and the use of a program advisory group.

The present paper will discuss the application of three of these requirements, related to driving session management, support to mentors and mentees, and communication with key stakeholders, in order to examine the program characteristics that are essential to successful operations. Some aspects of the principles (e.g., the policies that stipulate vehicle management, the use of a program advisory group) are managed at the statewide program coordination level and through the policy guidelines that are consistent across each program site. The review of statewide program policies is part of the broader evaluation study and is excluded from the present paper.

Method

The study results are based on triangulation of qualitative data from a driver mentor focus group, interviews with external program stakeholders, and an in-depth interview with the program site development officer (PDO), all of which were conducted as part of a broader program evaluation study. The driver mentor focus group participants (n = 7; 4 males, 3 females) had an average age of 47 years, and were predominately of Caucasian background, with one mentor being of a minority group. Four mentors were employed on a full-time basis, while three were unemployed at the time of the survey. The majority (4) of the mentor sample had achieved a senior high school certificate, trade qualification or bachelor degree, while two mentors had achieved a junior high school certificate. The majority of participants reported having prior experience with driver training/supervision or working with young people in general, and in such cases this was due to being a teacher, being a professional driver, and/or being parents themselves. The mentors had been involved with the BTC program for an average of 8.7 months, ranging from 6-15 months.

The external program stakeholders (n = 9; 8 females, one male) consisted of contacts from a range of sectors, including employment agencies, driver training organisations, community groups related to special needs sectors (youth housing, young women, youth justice and Indigenous youth), charity organisations, mining industry, and local Council and Chamber of Commerce members. No further demographic information was recorded.

An in-depth, focused interview was conducted with the site-based program development officer. The aim of the interview was to explore the main issues related to the strengths, weaknesses, strengths and opportunities of the program related to its current operations and context. An interview protocol was established to obtain information on these aspects for all interviews. Example questions included “What do you think is working well in the program?”, “What aspects of the program could be improved?”, and “What benefits do you see the program delivering to the community?”. Interviewees were also given the opportunity to comment on any other issue that had not been covered in the interview questions. Interviews took approximately one hour and all interviews were conducted face-to-face. All interviews were audio-recorded and transcribed, and a thematic analysis was conducted. Two researchers independently performed a thematic analysis of the transcripts, and consensus regarding themes was achieved. Direct quotes from the interviews are used to illustrate the themes reported in the following sections.

Results

Results related to selected essential requirements for Best Practice for LDMP program operation are discussed in the following sections.

Best Practice Essential Requirement: Ensure the driving sessions are well-managed

There was a strong consensus across all mentors and stakeholders interviewed that the provision of a manual transmission vehicle by the program is important so as to allow delivery of manual vehicle driving skills and licences. This was due to driving a manual vehicle being often required for employment, particularly in the rural setting where farm vehicles are typically manual rather than automatic. However, it was also highlighted that for safe operation in a learning situation, manual vehicles should be equipped with dual pedal controls and mentors should be appropriately trained in their operation. It was also recognised that the maintenance of manual vehicles can incur additional program expenses.

> "*I mean out here just about everything that you're going to do work-wise, you're going to need a manual licence, so the availability of the manual vehicle is really important*." (Program mentor, male)

> "*Manual cars are often used on farms and things, so there is a need for a manual licence for employment, like there are a lot of cleaning jobs at mining camps but they need to have a manual licence, so the agency struggles to fill these jobs. If they have an automatic licence, the agency can pay for specific driving lessons for a manual*." (Employment agency stakeholder)

> "*Manual cars are needed, but to avoid crash situations, these need to be equipped with dual controls, as well as an operator who is trained in using them. The expense of dual controls may be a barrier, as well as training the mentors to operate dual controls*." (Driver trainer external stakeholder)

A related finding concerned the matching of mentors and mentees. The Best Practice guidelines endorse matching mentors and mentees on various characteristics (such as common availability, gender, shared interests, personality and temperament, cultural/ethnic background, religion and language), and that learners perform the majority of their driving sessions with the same mentor, with some sessions performed with different mentors as the learner nears their practical driving test. Consistent with this, mentor and learner matching at the program site occurred, with the PDO undertaking each learner's first driving session with the program, in order to understand the learner's level of driving skill, experience and background, which would then be the basis of matching with an appropriate mentor. However it was found that it was not always practical and achievable, due to limited numbers of available mentors, and thus priority was given to matching for special groups such as Indigenous learners.

> "*Another thing too which is probably is a downfall for our mentors is that in a small town you find that we have all these groups and committees and you go to this committee, it's the same people at each committee. In a small town, each meeting I go to, I see the same people so it is to a point where you burn them out*." (PDO)

Matching was noted by both program staff and stakeholders as being particularly important for recruiting and engaging Indigenous learners, and having Indigenous program staff and mentors available at the site supported this.

> "*Who is running the program and who the mentor is, that will make or break the program. It doesn't matter how committed you are and want to do it, if you don't have the right people there, with the right communication, and you don't match the right skills, you're wasting your time."* (Indigenous/youth justice external stakeholder)

> "*We had an Indigenous learner who wasn't very confident in talking with people and so the PDO matched them with our Indigenous mentor; they [the learner] were very shy, didn't want to go with anyone, but they really wanted their licence, so the Indigenous mentor did a few sessions with them and the learner started to get more confident, and was right to drive with other people then*." (Program mentor, male)

While matching mentors and learners was seen as important, providing the learners with the opportunity to drive with mentors with whom they were less familiar was also seen to be beneficial in preparing the learners for their practical driving test.

> "*Because when you go for your actual driving test, you're sitting with someone you've never driven with…so it's good to get that exposure to different people, like different styles of working together*." (Program mentor, female)

Mentors viewed that providing learners with an opportunity to practice various skills, such as overtaking, driving at night, and driving vehicles of various sizes, is important for developing hazard perception skills related to judging distance and speed. The practical challenges of providing night time driving sessions to learners were highlighted, with learners often having difficulty obtaining this requirement outside the program, while staffing the program at night can be problematic.

> "*Put them behind the wheel at night time and for some reason, it's very different, and I've found a lot, they'll get their 80, 90 hours and have two or three hours night driving, for probably one or two of them Mum or Dad has taken them and sort of had their screaming match and 'nope, never taking me out at night again', then they get to 10 hours to go, and they've got eight hours of night drive to try and pull together*." (Program mentor, male)

Best Practice Essential Requirement: Provide ongoing support for mentors and mentees

It was evident from the focus group interview that program driver mentors are not purely instrumental, but contribute their own skills and experience, attitudes and beliefs, and personality. Several mentors were parents themselves, and reported drawing upon the experience of teaching their own children how to drive when operating in the program. Mentors reported that the atmosphere in the program was relaxed and comfortable, and it was evident that mentors sought available advice and assistance when needed, which was also facilitated by the PDO.

> "*I make sure my mentors go on that Keys2Drive (government-funded professional driving lesson), for mentor training as well as the learners…That one hour and they just sit back and observe the actual driving instructor, how they come across… because you're not in the car with [the mentor] every lesson so you don't know how they interact with the learner. I think updating mentors too with the road rules and communicating with the Department of Transport is very insightful too, cause we don't know when the rules are changed so we as PDOs try and get that first hand and inform our mentors as much as possible. That way we're not telling them the wrong thing*." (PDO)

Building a positive relationship with a local driver trainer who is willing to be available to the program for ongoing training and as a source of information for program mentors was viewed as very important to developing mentor knowledge and capabilities suited to their role.

> "*I have asked one of the driving school instructors that we have out [here] and he has had a one-on-one with the mentors, so that was very informative …one mentor was teaching or guiding the learner driver to use the mirrors for parallel parking, and that's a big no-no, it's not what they do in the test, so even having that one-on-one…that was fantastic so the mentor was very happy*." (PDO)

Within the program, the effort and commitment of mentors is acknowledged as crucial to the program's success and sustainability. As well as personal recognition and appreciation from the site PDO for mentors' time and efforts, mentors are also nominated for relevant volunteering and related community awards. Nominations and awards are communicated to program stakeholders, and are featured in the program newsletter. This was seen as contributing to the mentors' reported positive and rewarding program experience.

> "*I'll apologise [to a mentor] because a learner hasn't turned up so I've wasted their hour, and that's what happened to me today, I couldn't fit anyone in with him, but also too just having that one-on-one with the mentor and making them feel special, and that what they're doing is a fantastic job*." (PDO)

Similarly, the success and commitment of learner drivers engaged in the program is recognised in a number of ways. Photos of each licence achieved in the program are taken and posted on a 'Wall of Fame' in the program office. Success stories of learners, either completed or currently engaged in the program, are also featured regularly in the program promotional newsletter. These strategies were seen as a potentially effective in not only promoting the outcomes of the program and the success of its learners to the community, but also provided a way of demonstrating positive role modelling to potential learners.

Best Practice Essential Requirement: Maintain communication with key stakeholders

Regular contact with program stakeholders and promotion and activity within the community at large is undertaken by the PDO. This was facilitated by the PDO attending existing community interagency meetings, providing program updates including regular newsletters, holding education workshops, and being part of organised community events, as evidenced in the following quotes.

> "*[The external stakeholder organisation] have been very supportive…I invite them all along to whatever I'm holding, any functions and events and vice versa, so we keep communicating*." (PDO)

All stakeholders interviewed agreed that this aspect of the program operations was critical to their ongoing support and relationship with the program. In addition, for those stakeholders who referred their clients to engage in the program as a learner, there was a strong need for the program to provide feedback about their client's attendance, engagement and progress in the program. In the absence of such feedback, stakeholders may potentially assume that things are going well for their client, when in fact this may not be the case. Regular communication in this regard was considered to be crucial, and also provided a means for the program and relevant stakeholders to collaboratively problem solve any issues (e.g., client attendance) that arose.

> "*We get a monthly report, and we've just started a lot more engagement with [the PDO], so we had a meeting last week to discuss the program, so that we knew the nuts and bolts of becoming a mentor, what requirements it has, that sort of thing so that when we are*

talking with our community we might come across someone who might wish to be mentor or might come across a group or organisation that need the services of the Braking the Cycle program, so we work quite closely together, we correspond very frequently." (Local industry stakeholder)

"*It's kind of like unless you hear from [the PDO], you assume it's alright*". (Youth housing stakeholder)

It was also noted that there is some diversity in program activities between sites due to each site having different stakeholders who each seek varying outcomes from their relationship with the program. This particularly related to the level of program activity and outcome promotion that the PDO was expected to undertake. It was perceived that this was not unreasonable and could indeed benefit the program as well as the stakeholder, in that it promoted awareness of the program not only among potential learners, but also potential future mentors and stakeholders.

"*Even though the structure is still the same, my requirement is different from Beenleigh, from Crestmead…*" (PDO)

Also important was the ability of the program to link with existing community groups to build relationships and program awareness within the community, and generate ideas for cross-engagement.

"*In a small community we tend to see how we can all work together…we're helping each other out…it's that mutually beneficial relationship and being connected with other people*. " (Community centre stakeholder)

Discussion

The present findings help to illuminate the characteristics of LDMP program operations that are perceived, according to internal program staff and external stakeholders, as essential to success. A consistent theme across program staff and stakeholders is the importance of the program building positive and mutually beneficial relationships within the program and the external community. The existing connectedness of the community in which the program operates can also be harnessed, and is influential in program outreach, delivery and sustainability.

Matching learners with mentors is a Best Practice guideline requirement, but was found to be unrealistic in practice in a smaller community due to a somewhat limited number of available mentors. Nonetheless, it was found that matching for particular groups such as Indigenous community members is especially advantageous for their engagement in the program. While the guidelines also recommend matching learners with the same mentor for the duration of learner involvement, it was considered by program staff that in practice, exposure to different mentors, as well as different driving scenarios and vehicle types, was beneficial for building learners' driving skill and preparation for the practical driving test.

Providing ongoing support and training to mentors was also important to program staff, and this was facilitated by the PDO in building a positive relationship with a local professional driving instructor and providing information sharing opportunities. The program coordinator makes a concerted effort to treat mentors with respect and provide recognition for their efforts, which contributes to mentors having a positive and rewarding experience with the program. Similarly, providing recognition for learner achievements helped to create a positive environment for learners as well as facilitated promotion of program outcome delivery. Stakeholders agreed that regular communication and program updates are essential to stakeholder-program relationships. This also provides an avenue for further program promotion and problem solving.

It is evident that characteristics of the program location have a considerable influence on its operations. A number of factors related to Best Practice must be tailored according to the setting in which the program is operating. A strong point raised by program staff and stakeholders, while not explicitly stated as a Best Practice principle in the operations phase, was that the provision of manual vehicle driving skills (and thus manual vehicle availability) within the program is considered to be almost essential to employability in the rural community.

Limitations and conclusion

The data presented is preliminary and based upon selected findings of a broader case study. Several limitations to the information obtained must be considered. The study was aimed at providing in-depth information related to successful program operation, and one program site was suitable for selection, however this also represents a limitation in that the findings may not be entirely generalizable to other communities. In conducting the stakeholder interviews it was aimed to achieve broad representation across sectors, however it is possible that some relevant sectors may not be represented. While the number of participants in the driver mentor focus group was sufficient, the findings are based on information obtained from only one focus group, and not all available mentors were able to attend on the day. By nature of operating in a relatively small community, some sectors could only be represented by one person. As such, it is possible that the interview and focus group data do not fully represent the diversity of opinion. Further, self-report data is potentially vulnerable to limitations related to the accuracy of recall of situations and events. Finally, interviews of the mentees were not conducted as part of the current case study, however learner participant focus groups and surveys have been undertaken as part of the broader evaluation study. Broader evaluative research is recommended to address these limitations and strengthen existing understanding of the factors related to the success of LDMP operations within different settings. In conclusion, alignment with Best Practice guidelines is important for program implementation, however the study findings highlight the need for LDMP programs to be relevant and responsive to the requirements of the population and the context in which it is operating.

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Perceived risk, speed and countermeasures

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Abstract

A large number of factors (including road design, traffic volume, complexity) have been shown to influence the risk that drivers feel in any given situation. Previously we have shown that curves, hills, road width and median barriers were the road features that best predicted drivers' perceptions of risk. The present study examined the relationship between drivers' perceptions of risk and the speed they choose to drive. High definition video footage of a series of rural road sections was presented to participants whilst they were seated in the driving simulator. During the first part of the task, participants were asked to adjust the speed of the car to whatever they would choose if they were driving their own car. After this, participants were shown the same clips again (either at the speed they chose or at the speed the footage was recorded) and were asked to provide a continuous rating of how safe or unsafe they felt. Analyses revealed that higher speeds were associated with lower levels of perceived risk. In general, scenarios with high traffic volumes were driven at lower speeds and rated as higher risk compared to low traffic scenarios. Interestingly though, neither speed or risk ratings changed as a result of high traffic volume on roads with a wire rope median barrier. The presence of a police car led to the greatest reduction in speed. These findings provide insights into the relationship between risk and speed and the effectiveness of a range of countermeasures.

Introduction

The role of risk as an important factor in driver behaviour has been the focus of numerous studies. Some researchers have suggested that individuals drive in such a way as to maintain a zero level risk of crashing (e.g., Summala, 1988) whereas others (Wilde, 1998; Fuller 2008) suggest that each driver has 'preferred' or 'target' levels of risk and their driving behaviour (e.g., speed) is altered to ensure an acceptable level of risk is maintained. Indeed, several studies have found that perceived risk increases as speed increases (e.g., Fuller, 2008).

We already know that drivers form subjective judgements about risk as they drive (e.g., Groeger & Chapman, 1996; Pelz & Krupat. 1974; Watts & Quimby, 1980). More recently, Charlton et al (2014) investigated the relationship between drivers' perceived level of risk and the objective risk of a sample of New Zealand's state highways. In general, drivers' perceived ratings of risk corresponded well with the levels of objective risk and curves, hills, road width, and median barriers explained 80% of the variance in the participants' ratings of perceived risk. While this study provided useful information about factors that contribute to perceptions of risk on rural roads, we do not yet know how perceived risk influences the speed that drivers choose, and how this relates to specific risk countermeasures (e.g., lane markings, median barriers, signs). Thus, the aim of this study was 1) to investigate the relationship between drivers' perceived levels of risk on rural NZ roads and the speed they would choose if they were driving those roads and 2) determine the influence of specific road features on drivers' speed and perceived risk.

Method

Participants (n=52; 24 male, 28 female) with full driving licences were recruited for the study, and had an average age of 34 years (*SD*=11.97, range = 18-58 years). Ethical approval for the recruitment and test protocols was received from the School of Psychology Research Ethics Committee at the University of Waikato.

On arrival at the laboratory participants provided written informed consent. They then completed a simulator based speed and risk rating task. In brief, participants viewed high definition video of a series of road sections (recorded from the driver's perspective) whilst seated in the driving simulator. In the first part of the experimental session participants were asked to view the video clips and adjust their speed (using the accelerator and brake pedal) to a level that they feel comfortable with. After a short break, they viewed the same set of video clips and provided provide moment-to-moment judgments of driving risk (from "Safe" at one end and "Unsafe") using a small thumbwheel attached to the car's steering wheel that displayed their risk rating on a scale overlaid on the right hand side of the driving scene (based on Pelz and Krupat, 1974). During this part of the experimental session the speed of the vehicle was played back at either the speed the footage was recorded (n= 23) or the speed the participant chose during the first part of the session (n=29) (a "linked" condition). After this, participants completed demographic and driving history questionnaires and were thanked and given a $20 voucher.

Of particular interest were the speed and risk ratings for sections of video clips containing four types of road median (dashed white lines, double yellow lines, wide centre line and wire rope barrier) under high and low traffic conditions. In addition drivers' speed and risk ratings in response to two speed warnings, a police car and a high crash area sign were also compared.

Results

The correlation between perceived risk and speed was significant for the group that rated risk at the speed that the footage was recorded (r = -.76, p < .001) and for those rating risk at the speed they chose to drive (r = -.55, p < .001); in both cases lower ratings of risk were associated with faster speeds.

The speed that drivers chose under high and low traffic conditions with each of the four types of median in presented in Figure 1. A 2 (traffic) x 4 (median) repeated measures ANOVA revealed a significant interaction [$F(3,150) = 22.35$, $p <. 001$, $\eta_p^2 = 2.31$] and significant main effects of traffic [$F(1,50) = 298.73$, $p < .001$, $\eta_p^2 = .86$] and median type [$F(50, 150) = 42.18$, $p < .001$, $\eta_p^2 = .46$]. High traffic conditions resulted in slower speeds, apart from in the presence of a wire rope barrier. Under low traffic conditions, speeds were significantly slower in the presence of a wide centre line compared to a dashed white centre line ($p < .001$), but a wire rope barrier resulted in significantly higher speeds ($p < .001$). With high traffic, double yellow lines and a wide centre line led to reduced speeds compared to a dashed white line ($p < .001$) but as with the low traffic condition, the presence of a wire rope barrier led to increased speeds. Figure 1 also shows participants' speeds before and after passing a police car and a 'high crash area' sign. A 2 (hazard) x 2 (time) repeated measures ANOVA revealed a significant interaction [$F(1,50) = 44.47$, $p <.001$, $\eta_p^2 =.47$], and a significant main effect of hazard [$F(1,50) = 24.13$, $p < .001$. $\eta_p^2 = .33$] and time [$F(1,50) = 100.93$, $p <.001$, $\eta_p^2 =.67$]. Both hazards resulted in a significant decrease in speed (both p's <.001), but the police car led to a much greater decrease (15km/h compared to 2km/h).

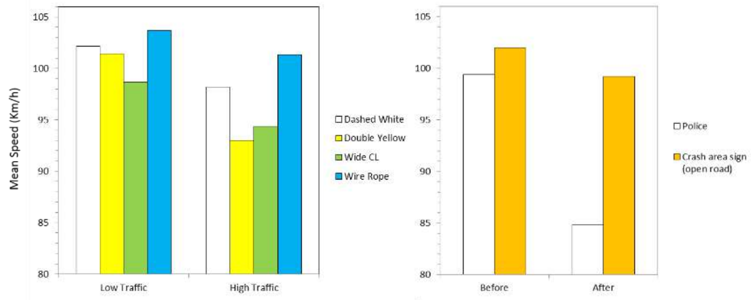

Figure 1. Mean speed in 1) high and low traffic conditions on roads with various median treatments and 2) Before and after passing a police car and high crash area sign.

Participants' ratings of perceived risk for each of the four median types in the high and low traffic conditions are shown in Figure 2. Participants rated high traffic conditions as more risky than low traffic conditions [$F(1,46) = 93.9$, $p < .001$, $\eta_p^2 = .67$] and there were significant differences in risk rating associated with the different median treatments [$F(3,138) = 15.07$, $p < .001$, $\eta_p^2 = .25$] with the double yellow lines being associated with the highest risk ($M = 3.60$), followed by wide centre lines ($M = 3.26$), and wire rope barriers ($M = 2.93$) and dashed white lines ($M = 2.97$) receiving similar ratings. There was a marginally significant trend for the group that rated risk in the linked condition to give higher ratings [$F(1,46) = 3.58$, $p = .06$, $\eta_p^2 = .07$], compared to those seeing the video at the initial speed. Across all of the clips, the speed participants chose to drive ($M = 99.10$, $SD = 3.8$) was significantly higher ($t(7) = 9.31$, $p < .001$) compared to the initial speed driven when the footage was recorded ($M = 94.20$, $SD = 3.1$).

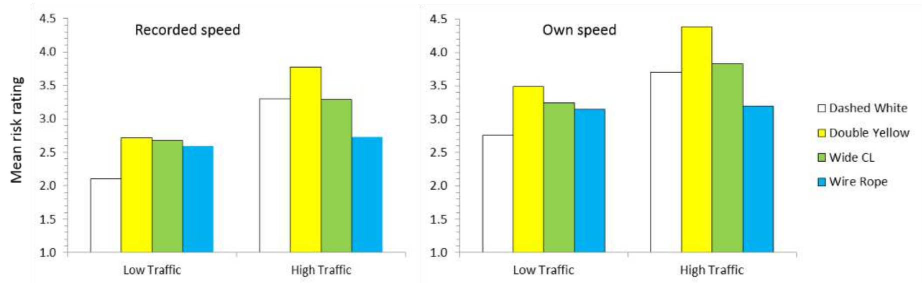

Figure 2. Mean risk ratings for participants in the high and low traffic conditions with four median treatments 1) viewing the clips at the recorded speed and 2) viewing the clips at the speed they chose to drive.

The risk ratings the two groups of participants gave when passing the police car and the high crash area sign are shown in Figure 3. Overall participants' risk ratings were significantly higher in the presence of the police car compared to the high crash area signs [$F(1,46) = 4.72$, $p < .001$, $\eta_p^2 = .09$]. Risk ratings were higher after passing the speed warnings compared to before [$F(1,46) = 13.39$, $p < .001$, $\eta_p^2 = .23$] and the participants' ratings in the linked speed condition gave significantly higher risk ratings those giving ratings at the initial recorded speed [$F(1,45) = 12.2$, $p < .001$, $\eta_p^2 = .11$], even though there was no significant difference ($p > .05$) between participants' chosen speeds ($M = 96.35$, $SD = 7.8$) and the speeds driven when the video was recorded ($M = 90.46$, $SD = 10.0$).

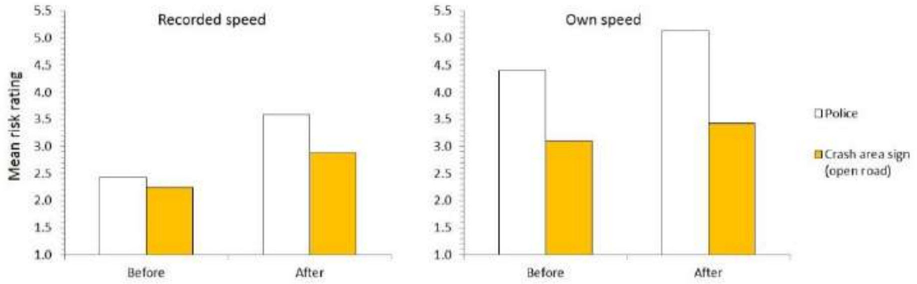

Figure 3. Mean risk ratings for participants passing the police car and high crash risk signs when 1) viewing the clips at the recorded speed and 2) viewing the clips at the speed they chose to drive.

Discussion

The aims of this study were to investigate the relationship between drivers' choice of speed and their perceived levels of risk on rural NZ roads and also to determine the influence of specific risk countermeasures on drivers' speeds and perceived risk. There were significant correlations between risk and speed with higher risk ratings associated with lower speeds. This may be due to the fact that in situations of perceived high risk, drivers are inclined to reduce their speeds. In the present experiment, drivers chose slower speeds and gave higher risk ratings when traffic was heavy. Interestingly, the presence of wire rope barriers appeared to mitigate the effects of higher traffic volumes, with drivers selecting similar speeds across both traffic conditions and their risk rating remained low. This suggests that drivers do perceive physical barriers from on-coming traffic as conferring a safety benefit. Areas with double yellow lines and wide centre lines however, appeared riskier to drivers compared to roads with dashed white lines. It is possible of course that drivers were responding to the road per se rather than the median treatment, but we think this is unlikely as roads were matched as closely as possible to ensure they had a similar visual appearance. The presence of a police car led to large reductions in speed and increased ratings of perceived risk. These changes were much greater than those observed in response to a high crash area sign, suggesting that a visible police presence on the roads is an effective way to reduce speeding.

Finally, providing participants with the opportunity to evaluate risk at the speed they chose (the linked condition) resulted in higher ratings of risk compared ratings given when watching the footage at the speed it was recorded. This increase could be a result of the higher speeds chosen by participants, or it may be an indication that participants are accepting of a higher level of risk (or task difficulty) than the recorded footage allowed. Further research using pre-recorded video presented at varying speeds may help to shed light on this issue.

Acknowledgements

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Profile of the speeding driver: Examination of driver attitudes and behaviour around posted speed limits on Australian roads.

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Abstract

Background: Vehicle speed is a key contributor to the incidence and severity of crashes. This research aimed to document the profile of drivers who self-report that they exceed the speed limit.

Method: Data were collected as part of a representative road safety survey of 5,179 drivers (45% male) in Australia. Drivers provided information regarding their usual speed choices across different speed zones as well as their recent history of traffic fines and crash involvement, attitudes towards local speed limits and Intelligent Speed Assist (ISA).

Results: Overall, 23% of the drivers reported exceeding the posted speed limit in a 40 km/h zone, while almost half of those surveyed (47%) exceeded posted speed limits of 100 km/h. Drivers aged 22-39 years reported the highest level of non-compliance with approximately up to 40% driving at least 10% faster than the posted limit. There were relatively few differences in speed compliance between male and female drivers, although older males reported greater non-compliance than similarly aged females. Attitudes toward ISA technology differed by age and gender.

Discussion: The findings highlight the age and gender based differences in attitudes toward regulated driving speed and adopted speed behaviours. Measures to improve speed compliance are discussed.

Implications: The findings can be used to improve the targeting of the road safety messages concerning speeding behaviour.

Background

Vehicle speed is a key contributor to the incidence (Watson, Watson, Siskind, Fleiter & Soole, 2015) and severity (Schuster, Nieuwesteeg, Northrop, Lucas & Smith, 2015) of motor vehicle crashes. Vehicle speed not only determines the stopping distance required to avoid collision, but also the force of the impact should a collision occur (Corben, van Nes, Candappa, Logan & Archer, 2010). Even a small reduction in speed can have a large effect on crash outcome, particularly in terms of injury to the occupants. This research aimed to document the profile of drivers who self-report they exceed the speed limit. Attitudes toward speeding behaviour and technology to improve speed behaviour were also sought. This information will inform road safety campaigns aimed at reducing speeding behaviour.

Methods

Participants and procedure

Data were collected in 2014 as part of large Community Engagement Survey initiated by the Transport Accident Commission (TAC), Victoria. A stratified sampling procedure was used to ensure the age and gender of respondents formed a representative sample of drivers from each

Australian jurisdiction (Victoria, New South Wales, Queensland, Western Australia, Tasmania, The ACT and the NT).

The survey was conducted by Ipsos Social Research Institute and administered online to Ipsos panel members. The survey contained a number of questions regarding attitudes toward road safety and technology to enhance road safety.

The final sample consisted of 5,179 participants licensed to drive a motor vehicle. Given that predetermined recruitment targets were established, it was expected that the age and gender distribution of the sample (displayed in Figure 1) would be representative of the broader Australian population. Comparison with recent census data confirmed this had been achieved (ABS, 2014).

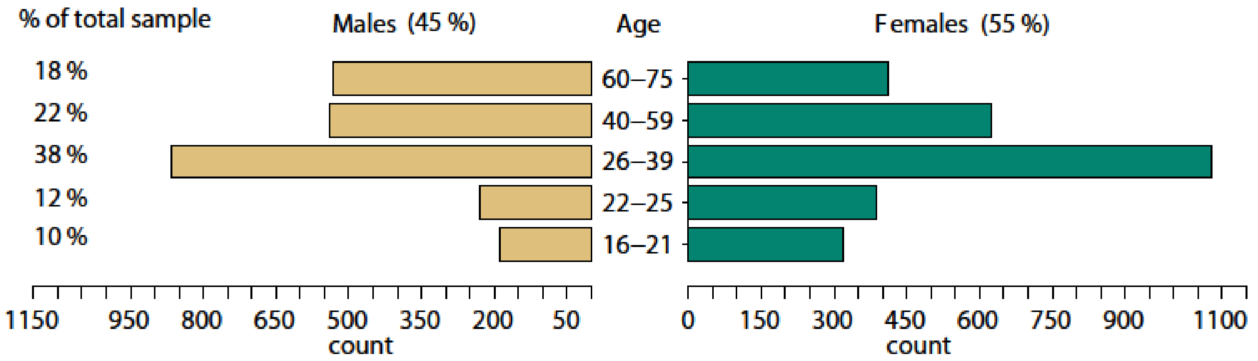

Figure 1: Unweighted data for age and gender distribution across the sample of licensed drivers (N = 5,179)

Community Engagement Survey 2014

The Community Engagement Survey sought information about the respondent (age, gender, occupation), their driving and licence history (frequency and type of travel, type of licences held) and their attitudes toward road safety and safety-related technology. Of relevance here, participants responded to a number of questions about their usual speed behaviours and opinions about speeding behaviour and Intelligent Speed Assist (ISA) (see Results for the questions asked). For the former, participants were asked what speed they normally drive in zones with posted speed limits of: 40 km/h; 50 km/h; 60 km/h; and 100 km/h. Responses were given according to a five point Likert scale (1 = below or at the speed limit; 2 = Up to 5 kms over the limit; 3 = between 6-10 kms over the limit; 4 = between 11 to 15 kms over the limit; and 5 = more than 16 kms over the limit).

Results and Discussion

Self-reported non-compliance with posted speed limits

Survey data were weighted by age and gender to adjust for discrepancies between the targeted and actual number of responses across the Australian jurisdictions.

As evident in Figure 2, a greater proportion of drivers reported exceeding the speed limit in higher limit speed zones, with 47% of the respondents exceeding posted speed limits of 100 km/h by at least 5 km/h or more. It can be observed that the extent to which drivers exceeded the speed limit also increased as the speed zone increased. In the slower zones, less than 1% of drivers reported driving 11 km over the posted limit in the slower speed zones of 40, 50 and 60 km, while 3% adopted these speeds in the 100 km zone. This may suggest drivers select speeds relative to the limit. For example, across all speed zones, very few drivers (less than 10%) reported exceeding the limits by more than 10%.

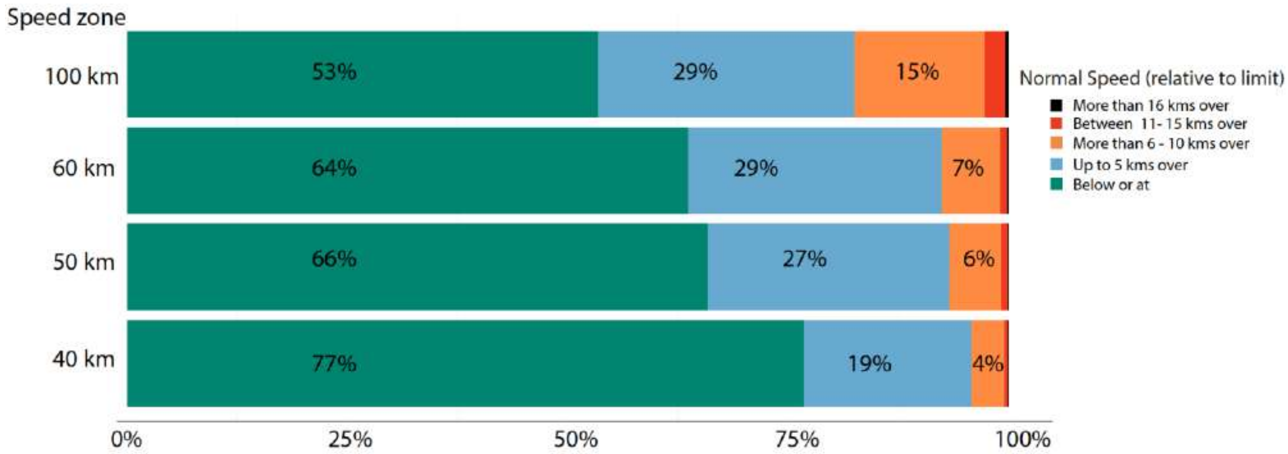

Figure 2. Self-reported "normal" driving speed relative to the speed limit (N = 5,082)

The age and gender distribution of drivers who reported non-compliance in at least one of the four speed zones was examined. Although non-compliant drivers (56%; n = 2,859) were more likely to be male (52%), 3-way chi-squares examining the association between age group, gender and compliance showed only one significant, and rather weak, effect of gender on compliance across the five age groups. Older males (aged 65 – 75 years) reported greater non-compliance than similarly aged females χ^2 (1) = 13.22, p <.001, Cramer's V=.10.

Non-compliant drivers were also more likely to be aged between 22 – 39 years (41%) with drivers in this age range being over-represented in the non-compliance group compared to the compliance group for both male χ^2 (4) = 43.04, p <.001, Cramer's V=.13 and female drivers χ^2 (4) = 42.81, p <.001, Cramer's V=.12. When the stated preference speed of drivers in this age range was examined across the four speed zones, approximately 40% drove 10% faster than the speed limit in 50 and 60 km zones and almost one quarter drove 10% faster in the 100 km zone. Therefore, not only do more drivers in this age range report exceeding the posted speed limits, the degree to which they exceed the limit is considerably higher than other drivers.

Table 1 displays predictors of self-reported non-compliance with the posted speed limits derived from logistic regression analysis. Respondents aged 22-25 and those aged 26-39 (64% and 65% non-compliers, respectively) had significantly higher odds of being non-compliers than 16-21 years old respondents (22-25 – OR 1.86, 95%CI: 1.42-2.45; 26-39: 1.77, 95%CI: 1.41-2.23); this effect was similar when compared to 40+ year old respondents. Males reported greater non-compliance than females and there were differences in self-reported non-compliance across jurisdictions. For instance, a lower proportion of respondents in Victoria reported non-compliance than in NSW (i.e., 49% vs. 60%: OR: 0.64, 95%CI: 0.55-0.74), whilst the higher proportion of non-compliance was from respondents resident in the ACT.

Table 1: Predictors of compliance / non-compliance with posted speed limits

	Compliance	Non-compliance	OR (95% C.I)
Age			
16 – 21	50%	50%	Reference (1)
22 – 25	35%	65%	1.86*** (1.42 – 2.45)
26 – 39	37%	64%	1.77*** (1.41 – 2.23)
40 – 59	48%	52%	1.12 (.89 – 1.39)
60 – 75	49%	51%	1.02 (.81 – 1.28)
Sex			
Male	42%	58%	Reference (1)
Female	47%	53%	.81*** (.72 - .91)
Residential			
Rural	44%	56%	Reference (1)
Urban	44%	56%	.95 (.84 – 1.07)
State			
New South Wales	40%	60%	Reference (1)
Victoria	51%	49%	.64*** (.55 – .74)
Queensland	45%	55%	.79** (.67 – .92)
Western Australia	39%	61%	1.03 (.84 – 1.26)
South Australia	48%	52%	.72** (.57 – .90)
Tasmania	50%	50%	.68* (.46 - .99)
Australian Capital Territory	26%	74%	1.83** (1.13 – 2.98)
Northern Territory	37%	63%	1.10 (.61 – 1.98)

***OR (Odds Ratio) significant at p <.001; ** p <.01; *p <.05

Attitudes toward speed behaviour and local speed limits

Figure 3 shows the three questions regarding attitudes toward speed behaviour, with responses separated between drivers who self-report compliance and non-compliance with posted speed limits. As is to be expected, the majority of drivers who agreed with the statement *"I drive over the speed limit if I am sure I will get away with it"* were non-compliant drivers (83%). This association was both significant and of medium strength (Cramer's V = .34) suggesting this to be an important consideration in a driver's speed choices. Likewise, over 70% of drivers who disagreed with the statements *"the chance of being in a crash is higher when driving 10 km more than the posted limit"* were also non-compliant drivers, although the effect sizes of these relationships were small (Cramer's V = .14 and .15 respectively). Therefore, it appears that for drivers who exceed the speed limit, being able to "get away with it" is a stronger motivator than perceptions of increased crash risk.

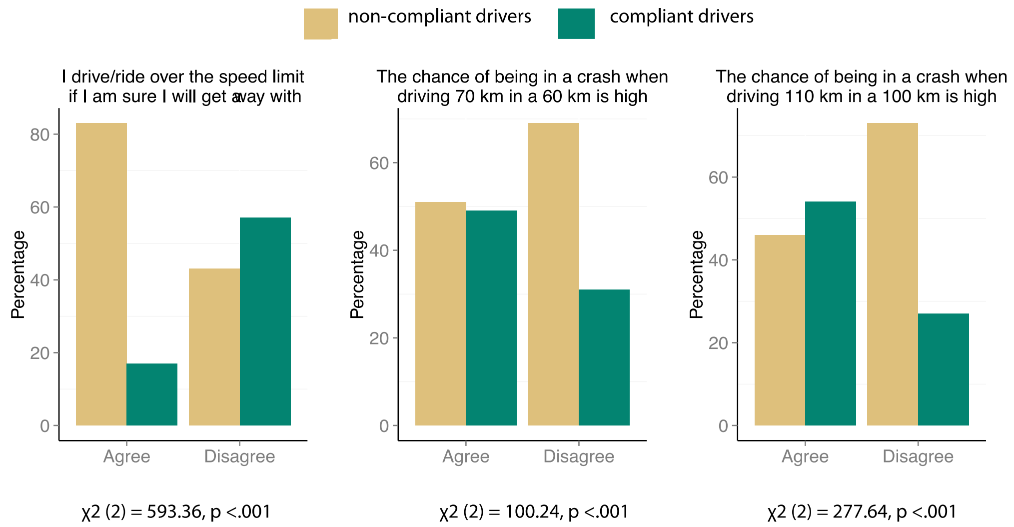

Figure 3. Attitudes toward speed behaviour across compliant and non-compliant drivers (N = 5,082)

Attitudes toward Intelligent Speed Assist (ISA) technology

Only one-third (n = 1,682; 32%) of the respondents had heard of ISA technology. The majority had not (n = 2,318; 45%) or were unsure if they had (n = 1,179; 23%). Respondents were given a description of ISA, including an image of the device. When asked whether ISA would be useful for the respondent as a driver, 4,735 responded and of those only 10% (n = 470) agreed that ISA would be useful. The majority (60%) disagreed, while 30% neither agreed nor disagreed. Of those that agreed, 76% were non-compliant drivers χ^2 (2) = 87.42, p <.001 Cramer's V = .13, suggesting ISA technology would be welcomed by some non-compliant drivers.

Gender was associated with opinions on the usefulness of ISA technology. Significantly fewer female drivers (40%) agreed that ISA would be personally useful than male drivers (60%), while significantly more female (54%) than male drivers (46%) had no opinion χ^2 (2) = 30.65, p <.001, ω = 08. When these were examined across the five age groups, the relationship was only found for drivers aged 26 to 39 years χ^2 (2) = 17.89, p <.001 Cramer's V = .11 and those aged 40 to 59 χ^2 (2) = 7.48, p <.001 Cramer's V = .07 where significantly more males (65% and 55% respectively) than females (35% and 45% respectively) agreed with the usefulness of ISA.

Conclusion and Implications

In a representative sample of drivers in Australia, age and gender based differences were found for attitudes toward regulated driving speed, technology to enhance safety and adopted speed behaviours. Non-compliant drivers were mostly younger drivers aged 22 to 39 years. Non-compliance was associated with the belief that drivers would not get caught when speeding. There were some differences across jurisdictions in self-reported compliance, which may be a product of the level of speed enforcement undertaken, general culture toward road safety, and / or vehicle use and geography, although we are unable to comment with certainty on the underlying reasons for this, and this could be the subject of future research. These findings can be used to improve the targeting of the road safety messages concerning speeding behaviour. In particular, with more tailored strategies to address potential misconceptions regarding speed enforcement, speed danger, and the benefits of ISA technology.

Acknowledgements

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Trouble in paradise: a systems analysis of beach driving fatalities on Fraser Island (K’gari)

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Abstract

Beach driving remains a necessary form of transport in Australia, however it is not without incident. Between 2002 and 2015 there were over 160 reported 4WD crashes, including 4 fatalities on Fraser Island (K'gari), off the Queensland coast, Australia. Although beach driving provides a unique driving environment, there is little research investigating the causal nature of such crashes. The paper first reviews the cornerstone areas of the National Road Safety Strategy, in light of this unique driving environment. It also considers the guiding principles of the associated Safe System approach, before describing the results of applying two sociotechnical systems analysis approaches to this complex driving environment and a fatal crash. First, Cognitive Work Analysis was used to describe the K'gari beach driving 'system' along with constraints impacting driver behaviour. Second, Accimap was used to describe the contributory factors involved in a fatal 4WD beach driving accident that occurred in April 2009. The findings show that beaches present as complex roadway environments with a range of often conflicting priorities. Further, the analyses show that beach driving collisions likely involve a larger range of systemic failures than previously identified. In conclusion, the paper discusses the possibilities of Safe Systems interventions in light of the outlined sociotechnical systems approach. The details of current beach driving research are provided, while an overview of the ongoing research agenda is articulated. This agenda seeks to enhance our understanding of cultural, economic, environmental and social implications of off-road and beach driving to improve safety and stakeholder coordination.

Introduction

Fraser Island or K’gari (paradise) in the language of the local Butchulla aboriginal people, is world heritage listed and is the largest sand island in the world. It is located off the southern Queensland coast, Australia and is 120 kilometres in length and approximately 24 kilometres at its widest point (Figure 1). It has a residential population of less than 200, yet it receives more than 390,000 annual visitors in the form of daytrips and short term stays. It is a popular destination for local, national and international tourists, with more than 80% of visitors camping in designated areas along the eastern beach. Access to the island is by barge while access and travel on the island is afforded by the use of 4WD vehicles traversing the eastern beach and sandy inland tracks.

Figure 1. Fraser Island (K’gari) geographic context (Source: Google Maps).

The beaches of K'gari, like any Queensland beach on which vehicles are permitted to drive, are considered gazetted roads under state government legislation. That is, all road rules and regulations that pertain to state government constructed and managed roadways, also apply to the beaches. While this allows for greater regulation, enforcement and prosecution, it is not without issue.

When considering the cornerstone areas of the 'safe systems' National Road Safety Strategy – Safe Roads; Safe Speeds; Safe Vehicles; Safe People (ATC 2011) – it becomes apparent how unique the beach driving environment is. Moreover, the need for a focussed strategy is highlighted. As a gazetted roadway each of these safety approaches should remain and be prioritised, however the nature of the four pillars appears distinct to the beach driving environment. *Safe Roads* seeks to ensure the driving surface is designed and maintained to reduce risk, however the beach as a road is maintained and influenced simply by wave action and seasonal variation. In fact, there is very little physical intervention to the beach driving surface by the authorities in line with its National Parks and World Heritage status.

Safe Speeds is intended to complement the road environment and seek road user compliance to limits. However, the beach as a roadway is predominately an 80km/hr driving environment that experiences rapid changes, unstable surfaces, pedestrian priority, and distraction – with limited signage, instruction or road infrastructure. It is questionable whether applying conventional road speed limits in the beach environment is appropriate. Further as a gazetted roadway it permits any person with regular on-road or international licensing to drive in this complex environment.

Safe Vehicles has the strategic intent of lessening the likelihood of crashes and simplifying the driving task through the design of the vehicle. In the beach environment not only is it a roadway context of vast unfamiliarity for many drivers, it is further compounded by the necessity of the use of 4WD vehicles which have high rollover risks for inexperienced drivers (Keall and Newstead 2007). Moreover, there is a lack of control on which vehicles can be used when driving on the beach.

Safe People seeks to 'encourage safe, consistent and compliant behaviour through well informed and well educated road users' (ATC 2011 p 41). As a gazetted roadway it is possible for the authorities to regulate and enforce specific behaviours on the beach. However, there are limited requirements for specific education when using the beach as a road. Only those drivers who seek organised tours are required to view specific safety information about beach driving. What is recognised in this paper is that these strategic cornerstone areas of road safety, are not well supported in the beach driving environment.

Unsurprisingly then, crashes occur. K'gari has seen numerous incidents and most significantly 4 fatalities from 3 separate accidents since 2009. Three of the deaths resulted from two motor vehicle accidents that occurred in 2009. These fatalities were passengers in 4WD hire vehicles being driven by a fellow tourist, who they had only recently met, driving on sand for the first time. The fourth fatality in October 2014 was the driver of the vehicle and was killed when her vehicle overturned on an inland sand road.

At the time of the 2009 accidents international tourists were permitted to undertake self-drive tours of the island. Since 2011 these tourist groups are required to be part of 'tag-a-long' tours. While they still self-drive, they are part of a convoy of up to 6 vehicles that is led by an experienced 4WD operator from the tour company. The most recent fatality occurred while the tourist in question was participating in this type of monitored 4WD excursion. Prior to departure the designated tourist drivers of the 4WD vehicles are required, by law, to view a 30 minute instructional video, undertake a vehicle inspection and complete a 30 minute test drive of their designated vehicle. This instruction is provided by the tour company.

There is no doubt that beach driving crashes represent a significant problem. As a result, standard road safety interventions are being applied, particularly when visitor numbers are high. These include the use of speed cameras and random alcohol and drug testing. Whilst this is encouraging, the program of research from which this paper derives argues that the unique context in which beach driving occurs raises questions regarding a standard road safety approach. This research seeks to take a socio-technical systems view of this road safety issues (see Salmon and Lenne, 2015), as such it is useful here to acknowledge the differences between this approach and that of the current 'Safe System' approach adopted through National Road Safety Action Plans (ATC 2011).

While the safe systems approaches do contain elements of systems thinking, it has been pointed out they are not underpinned by socio technical systems (STS) thinking models or methods. Salmon and Lenne (2015), however, point out that whilst there is confusion about 'systems' approaches, some of the key principles of STS are present in current road safety thinking. For instance, the acknowledgement of human fallibility; the understanding that the principles of road safety are a shared responsibility across stakeholders; and the consideration of factors beyond road users, such as roadway design and vehicles. Such parallels are aligned with STS thinking approaches such as Rasmussen's (1997), yet the differences are also significant. Consider, for example, the current road safety strategies focus on behavioural failures as 'error' (ibid); and conversely that STS thinking views the overall system as the appropriate unit of analysis. Further, STS considers that interactions, not components, are of most interest when seeking to understand behaviour, and largely moves away from the approach which typically focusses on road users themselves (Salmon and Lenne 2015).

Indeed, through an STS approach this research anticipates that the unique nature of beach driving environments may provide an opportunity to implement new context driven interventions. A first step in determining this requires that the beach driving context be described and understood, along with the systemic factors that contribute to beach crashes. In particular, the extent to which the environment and associated crashes are different to standard road environments and crashes needs exploration. In addition, the stakeholders who share responsibility for beach driving crashes should be identified. This paper is a response to this, exploring the beach driving environment and also highlights the contributory factors involved in the April 2009 incident which resulted in 2 fatalities.

Description of the 18th April 2009 crash.

On the morning of 17th April 2009, a group of 11 foreign tourists hired a 4WD from a vehicle rental company in Hervey Bay, Queensland. The designated drivers of the group were shown a 10 minute safety induction video, whilst some shopped for groceries, and others packed the luggage on the 4WD vehicle. The vehicle itself was an 11 seater 8 cylinder diesel 4WD with a seat configuration of 3 across the front and 8 passengers on 2 bench seats facing each other in the cabin. The group signed rental agreements, were further briefed on engaging the vehicle in 4WD and the benefit of reduced tyre pressures if stuck in soft sand. They were provided with maps and itineraries and they departed. The groups journey to, and on K'gari that day were uneventful and they rendezvoused with other groups at a designated campsite for the evening.

The group departed early on the second day (18th April), heading north on the eastern beach for a destination known as Champagne Pools. After a short time one of the individuals who had packed the luggage at the hire company and was not a designated driver asked if he could drive, a request which was granted. After travelling for perhaps 10km, one of the designated drivers noticed that they were getting close to the water's edge. The driver subsequently swerved sharply to the left to avoid a wave, losing control of the vehicle which rolled 3 ¾ times. Two individuals were thrown from the vehicle and killed, while 5 others were seriously injured.

The response to the incident is also noteworthy. A Queensland Parks Services Wildlife Ranger was the first on the scene, shortly followed by two others leaving one to summon emergency assistance. The lack of communication facilities made the access to medical assistance very slow. The crash occurred at around 7.30am, Police and Ambulance Services were notified at 7.55am and 7.56am, not arriving at the scene until 8.40am and 8.45am respectively. The two helicopters required to evacuate patients did not arrive on scene until 9.18am.

Method

There is a growing body of research involving the application of so-called systems thinking theories and methods to road safety issues (see Salmon and Lenne, 2015). These approaches have been prominent for the last two decades in the area of accident analysis generally (e.g. Leveson, 2004; Rasmussen, 1997) and have also enjoyed significant attention in the areas of systems analysis and design (Karsh et al., 2014; McIlroy and Stanton, 2011; Salmon et al., 2012). The philosophy is that accidents, and indeed safety, are emergent properties that arise from non-linear interactions between components across complex sociotechnical systems (e.g. Leveson, 2004). In short, accidents are underpinned by a network of interacting, contributory factors covering a range of actors and artefacts and are not simply the product of one bad decision or action alone. In a driving context, this suggests that, even in crashes that have direct driver-related causes, there are a range of other contributory factors worthy of investigation.

Two systems approaches were used to investigate the beach driving environment and beach driving fatalities on K’gari. Cognitive Work Analysis (CWA, Vicente, 1999) is a framework used to identify constraints on activities and then support the design of new systems (Vicente, 1999). To better understand the beach as a roadway environment this study developed an abstraction hierarchy from the first stage of CWA - Work Domain Analysis. Accimap is an analysis framework (Rasmussen, 1997) which is used here to represent the causal network underpinning the fatal incident of 18th April 2009 across six organisational levels: 1. government policy and budgeting; 2. regulatory bodies and associations; 3. local area government planning & budgeting (including company management); 4. technical and operational management; 5. physical processes and actor activities; and 6. equipment and surroundings.

Results

Work Domain Analysis

Key inputs for the WDA Abstraction Hierarchy (AH) were identified from three sets of resources: 1. The regulation of the ‘beach as a road’ defined by Queensland government transport related legislation and policy; 2. The road safety literature and departmental guidance concerning beach driving; and 3. The observation and inspection of the beach driving environment on K’gari.

The AH is presented in Figure 2. Due to space constraints the top three levels are represented in full while the bottom two have been summarised only. While there is much that can be drawn from this representation, this paper will only outline some key insights.

The highest level of the abstraction hierarchy describes the functional purpose of the ‘beach as a road’ system. Two overall purposes were identified, the first is ‘safe vehicle access to (coastal) destinations’; while the second is to ‘limit the need for roadway infrastructure’. What is immediately recognisable is that these two functional purposes are likely in conflict – it is questionable whether it is possible to prioritise safety whilst at the same time limiting roadway infrastructure.

The next level details and links the measures or values that enable progress towards the functional purposes to be understood. While six values were identified, only three connect to both functional purposes. Maximise compliance; safe passage/movement of vehicles; and maximise conformity with relevant standards and regulations are important to both purposes. The system described here considers that minimise environmental damage is not a measure for ‘safe vehicle access to (coastal) destinations’ indicating a probable conflict between the world heritage status of K’gari and the prioritisation of unrestricted visitor access. Again this conflict is noteworthy, as interventions designed to improve safety will have to have only minimal impact on the environment.

The purpose related functions within the middle of the AH represent the functions required for the system to fulfil its purpose. Within this system ten purpose related functions were identified. A useful way to conceive these functions is through means-ends relationships. For example if the generalised function of ‘driver training’ represents the question **‘what’**, then ‘minimise trauma and collisions’; ‘maximise compliance’; minimise environmental damage’ and ‘maximise conformity with standards and regulations’ is **‘why’**; and then object related processes of ‘provides rules about behaviour’; ‘inform / educate road users’; ‘impacts vehicle operation’; and ‘provides information about speed’ is **‘how’** the generalised function of ‘driver training’ is achieved. What is interesting is that while driver training is explicitly required as a function in the ‘beach as a road’ system, it is seemingly not being adequately met.

At the bottom of the hierarchy are the physical objects that are found in the ‘beach as a road’ system. The inspection of the beach revealed a number of unique physical objects for a roadway, including the ocean and waves, shipwreck, aeroplane, creeks and wash outs, rocks, logs and wildlife. This system also contains a number of expected roadway elements including speed signage and information signage. Importantly it also include those objects which while physically located away from the beach environment, are of significant influence on its use as road, for example road rules, finances, legalisation, and maintenance guidelines.

The level above the physical objects represents the ‘affordance’ or the functional capacities of the physical objects. For example consider the affordance of ‘surface for mobility’ as an object related process of hard sand. What is interesting is that affordances may be linked to multiple objects, and from a system perspective here is where opportunities and constraints may be recognised. For example the object related process of ‘depict path’ is an affordance of ‘hard sand’; ‘soft sand’; ‘puddles’; ‘creeks & wash outs’; ‘tyre tracks’; ‘undulations’; ‘vehicles’; and uniquely on the beach as a road ‘aeroplanes’.

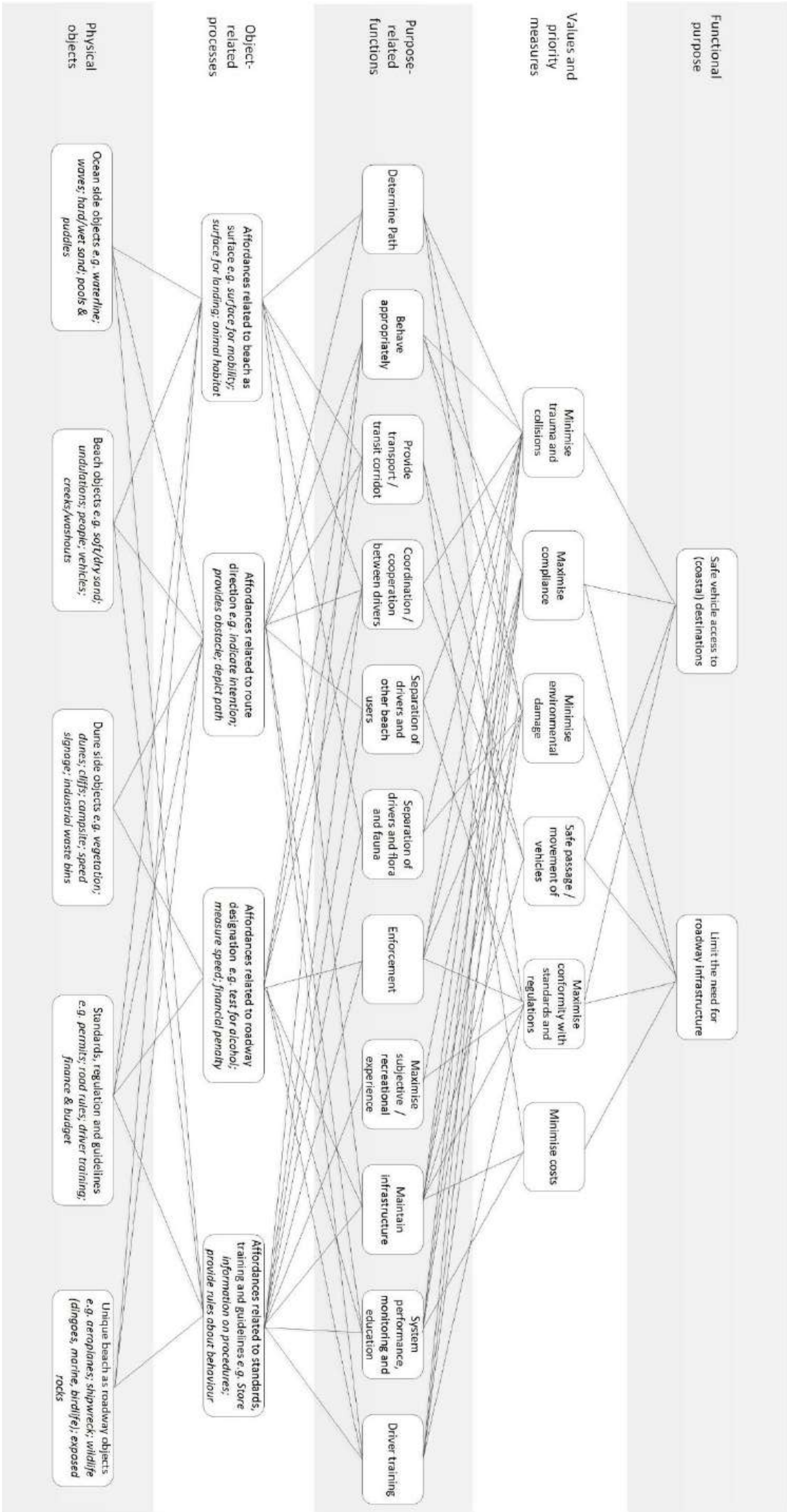

Figure 2. Beach as a road - Work Domain Analysis, Abstraction Hierarchy

Accimap

The data for the development of the Accimap was obtained from the Coroner's report on the driving fatalities that occurred on K'gari (Queensland Courts 2010). This details the circumstances of two independent fatal motor vehicle incidents in 2009. The report outlines the evidence in both incidents and importantly it describes the circumstances surrounding the hiring of the vehicles; driver training, the vehicles specifications; the crashes themselves and the emergency response. This paper presents an analysis from one of those which resulted in the deaths of two foreign tourists in April 2009.

The Accimap is presented in Figure 3. At the top level, government policy and budgeting, sits a report commissioned by the Queensland State Government in 2005 which made a number of recommendations for the safety of the use and hire of 4WD vehicles on K'gari. Rather than influence behaviour, this is included as these recommendations were only implemented following the fatal incidents of 2009.

The Coroner's Report makes no references regarding contributory factors that may be included within either the 'regulatory bodies and associations'; nor the 'local area government planning & budgeting' levels. What is known, however, is that a range of important stakeholders reside at these levels, including Queensland government departments related to the administration and management of emergency services and the environment; the relevant local government; and also management associations for environmental protection and accommodation on K'gari (Stevens and Salmon 2015). It is likely that further analysis of this incident would also identify contributing factors at this level.

At the technical and operational level, miscommunication and ambiguity about the driver's roles can be found. This led to the provision of inadequate driver training at the physical processes level prior to the incident.

The physical processes and actor activities level describes the activities leading up the crash itself. This level is focussed on the driver, the relationships between driver training and experience, and their ability to respond to the beach driving environment. Here the driver had no previous experience of driving on sand, had received only limited driver training, and was apparently exceeding the speed limit (Queensland Courts, 2010). The Accimap shows the consequent sharp turn, together with the sand surface, top loaded luggage, and the nature of the 4WD configuration all contributed to the rollover. However, following the rollover there are other contributory factors that determine the extent of injuries and the fatalities, including the failure of passengers to wear seatbelts, the lap belt nature of the restraints, and the delayed emergency response.

The equipment and surroundings level shows the beach environment and vehicle factors that contributed to the incident. The waves (and the vehicles proximity to them) initially caused the driver to swerve, and the nature of the sandy surface in conjunction with the vehicles speed and luggage load were deemed to have caused the vehicle to roll over. Following this aspects of the vehicle are important. The seat configuration in the vehicle and use of lap belts ostensibly contributed to the injuries incurred. Finally, the poor mobile phone network was a major factor in the delayed emergency response.

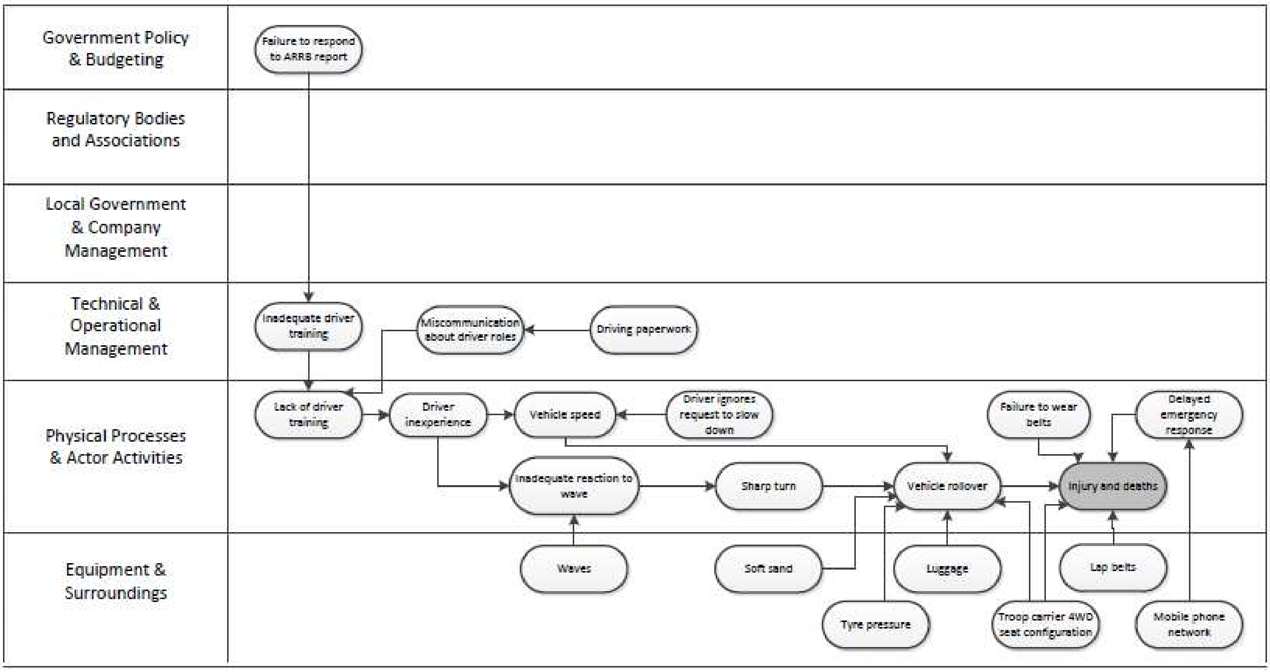

Figure 3. Accimap Analysis – Accident trajectory of 18th April 2009

It is highly likely that there are additional factors outside of those expressed in the Coroner's report, that a systems investigation and approach to the incident may be expected to reveal. Perhaps from both the Regulatory and Company Management organisational levels there are necessary links to the provision of driver training.

Discussion

The exploratory analyses presented here confirm that beach driving systems are unique complex environments in which a systems thinking approach to accident analysis and prevention is warranted. Both the WDA abstraction hierarchy and the Accimap analyses provide a picture of a complex, high risk driving environment in which there are multiple factors influencing driving and indeed safety. A key conclusion from this case study is that standard road safety approaches to accident analysis and prevention in beach driving are not appropriate. Rather, it is these authors opinion that interventions need to be developed based on the unique nature of the driving environment and its constraints. When considering the key cornerstone areas of road safety intervention and the systems analysis overview presented here – the difficulties of implementation becomes evident. For example, there are very few opportunities for traditional safe roads design and management interventions. However when the pathways drivers take are determined largely by previous vehicles, is there a collective reinforcement of safe or indeed unsafe driving behaviour? When considering speed and human tolerance to impact forces on beach road surfaces – what kinds of speeds are in actual fact absolutely safe? Further research is therefore required in this context to develop approach beach driving safety strategies.

In the first instance the research agenda will focus on gathering data which will both inform a socio technical systems response to beach driving, but also value add the current strategic intent of the National Road Safety Strategy (ATC 2011). Key requirements to support this include understanding the physical and jurisdictional conflicts and opportunities for the design and maintenance of the beach as a road. Exploring the context of speed, and the posting of speed limits within a safety infrastructure constrained environment. While the use of vehicles is limited to 4WDs, there are lessons to be learned from the vehicle to vehicle and driver to driver awareness and conventions that occur in the beach driving system. Finally, what are the opportunities for well informed and educated road users in this dynamic driving environment – what role and impact does current licensing, training, enforcement and regulation play in managing road safety on the beach? Principles tasks to support this will include new crash data collection and analysis systems, the exploration of context-driven safety interventions, and potentially a new approach to regulation.

In light of this further research exploring beach driving is required. This will reveal much more than simply a safety approach to beach driving. Through the lens of this particular off-road and infrastructure deficient environment there will also be applicable lessons to a range of national and international loose surface driving contexts. The significance and potential impact of this new knowledge cannot be understated, take for example in Australia where more than half of the 820,000km of roads are unsealed, and internationally, where in second and third world countries unsealed roadways may constitute more than 75% of the national roadway network (CIA 2014).

A research agenda has been established to seek to address the current research deficiencies and explore the potential for a range of safer driving environments. Initial research, currently underway seeks to further explore the beach driving systems from the driver perspective. The aim of this project is to develop an initial understanding of a driver's perceptions and reactions to driving on gazetted beach roadway environments. The objectives of this research are to: 1. Identify the range of physical and cognitive processes a driver undertakes in order to navigate the beach driving environment. 2. Identify the range of physical elements a driver encounters within the beach driving environment. The drivers will think aloud whilst driving, as a component of a data collection method called Verbal Protocol Analysis (VPA). They will also complete a survey at the conclusion of the driving task. The verbal protocol analysis approach has become popular as a way of assessing behaviour and cognitive in real world contexts with many recent applications in road safety studies (e.g. Salmon et al, 2013; Walker et al, 2011).

The broader program of ongoing research will seek to have two main aims; first it will undertake appropriate systems modelling of driving safety in beach and unsealed roadway environments, and, second, it will establish appropriate crash data systems to elucidate the full network of contributory factors involved in beach driving and unsealed roadway crashes. This will involve a series of targeted research activities, including development and testing of crash contributory factor classification schemes, the conduct of reliability and validity studies, prototype testing, and full scale trials over the next 36 months.

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Observations of Road Safety Behaviours and Practices of Motorcycle Rickshaw Drivers in Lahore, Pakistan

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Abstract

Motorcycle Rickshaws (MRs) are an informal paratransit mode in Pakistan. They are locally manufactured and very popular but there are concerns about their crash involvement and overall safety. The first study of the current PhD program revealed that rickshaws (both MRs and auto-rickshaws) were involved in 51,992 road crashes attended by emergency ambulances in Punjab province, Pakistan between 2011-2013. This study aims to examine the road safety behaviours and practices of Motorcycle Rickshaw Drivers (MRDs) that may be contributing to these crashes. MRDs were observed at 12 major signalised intersections in Lahore. Vehicle characteristics and driver behaviours were recorded using a paper-based survey between 9am-7pm for a full week in May 2015. Of the 500 MRDs observed, about 23.4% appeared to be younger than the minimum driver licensing age of 18 years. More than half (52.6%) of the MRDs entered on the red light and 17.4% crossed when the signal was turning from yellow to green or red. MR traffic conflicts were observed in 62.8% of cases and one crash and 15 near-miss crashes were witnessed. Additionally, about half of MRs were overloaded, no MRD wore a helmet, and 3.8% were using a mobile phone while driving. This study provides the first scientific evidence to substantiate public concerns regarding the safety of MRs. It demonstrates that about a quarter of MRDs are underage, almost half of MRs are overloaded and more than half disobey traffic signals. This research could inform authorities to manage MR related transport and road safety issues.

Introduction

Road traffic crashes and injuries are a major public health concern globally. Every year about 1.24 million fatalities and 20 to 50 million injuries occur due to road traffic crashes (WHO, 2015). The burden of road crashes and injuries is disproportionately distributed among the developed and developing world. Low-income and middle-income countries (LMICs) share 91.5% of global fatalities, despite having only 47.9% of the total registered vehicles (Bowman, Fitzharris, & Bingham, 2013, WHO, 2015).

Pakistan has the fifth largest number of road fatalities in the world (around 40,000 fatalities per year) (Kayani, Fleiter, & King 2014; WHO, 2009) and it has been estimated that over two million road traffic injuries occur in the country every year (Ahmed, 2007; Bhatti & Ahmed, 2014). Despite the increasing number of road crashes, road safety is not recognized as an important public health issue in Pakistan; instead it is considered an insignificant issue for which the transport sector or police department are responsible (Batool, Carsten & Jopson, 2011; Ghaffar, Hyder, & Masud, 2004). There is an absence of road safety policy at national and provincial levels and no planning exists for non-motorized and vulnerable road users (Batool et al., 2011; Hyder, Ghaffar, Sugerman, Masood, & Ali, 2006; Imran, 2009). Traffic laws (e.g. helmet wearing, seat belt, speeding etc.) exist but law enforcement is weak or absent, so compliance is very low in most parts of Pakistan (Hyder, Ghaffar, & Masood, 2000; Batool et al., 2011; Hashmi, Tahir, Akbar, Naseer, Rashid, & Zia, 2012; Klair & Arfan, 2014; Tahir, Naseer, Khan, Macassa, & Hashmi, 2012; Tahir, Macassa, Akbar, & Naseer, 2013). The public transport sector is largely dominated by the private sector, as government has failed to provide adequate infrastructure and quality transport services for the rapidly growing population (Imran, 2009; Masood, Khan, & Naqvi, 2011; Muhammad, 2013).

Various innovative modes of transport have become widespread in Pakistan to fill the gaps in public transport availability, including Motorcycle Rickshaws (MRs). MRs are 100cc motorcycle-driven three-wheeler vehicles (Figure 1) where the rear wheel of the motorcycle has been removed and a two-wheeled open-sided cart is attached to it. The cart has a nominal seating capacity of six passengers. MRs differ from conventional Auto-rickshaws (ARs) in several ways: ARs have an enclosed cabin and passenger tray (Figure 2) and a seating capacity of two to three passengers. ARs are a regulated paratransit mode in Pakistan, while MRs are an unregulated informal paratransit mode.

Figures 1 -2: Motorcycle Rickshaw and Auto-rickshaw in Pakistan (Source: Author)

Figure 1: Motorcycle Rickshaw

Figure 2: Auto-rickshaw

There is a scarcity of research on MRs in Pakistan, with most of the available information being found in newspaper articles regarding their proliferation and safety. Two newspaper articles (The Express Tribune, 2013a,b) claim that there are around 50,000-70,000 MRs in Lahore, over 100,000 in Karachi and they operate in cities, towns and villages across the country. One of major reasons for the large growth of MRs is their informal status and unregulated operation. The government has not yet regulated MRDs, so anyone with a motorcycle licence can become an MRD (many drive unlicensed), there are no route permits nor any vehicle fitness certification. Therefore, MR driving provides an easy entry to the job market for unskilled and unemployed people (The Express Tribune, 2012, 2013a; Khawaja, 2011; Siddiqui, 2014; Sarfraz & Hussain, 2010; Sargodha News, 2014; The Nation, 2012).

MRs are also cheaper than ARs, costing about AUD$1000-1200 (The Express Tribune, 2012) and in Lahore second-hand MR bodies are also easily available (AUD$200-400) that can be fitted to any 100cc motorcycle by a local welder. Currently, there are 46 MR body manufacturing companies and 22 motorcycle companies operating in Lahore (General Manager Planning - Lahore Transport Company, personal communication, May 15, 2015). The government has not formulated any engineering standards for MR manufacturers, so many variations in MR designs exist across Pakistan. Newspaper articles have expressed concern that these modifications may compromise the safety of MRs (The Express Tribune, 2011, 2012, 2013a).

Various newspaper articles and blog posts have also expressed concerns that MRDs are involved in speeding, overtaking, overloading, unlicensed and underage driving (Figures 3-5), setting up of illegal terminals and endangering the safety of pedestrians and other road users (The Express Tribune, 2011, 2012, 2013a; Khawaja, 2011, Siddiqui, 2014; Sarfraz & Hussain, 2010; Sargodha News, 2014; The Nation, 2012).

Figures 3-5: Overloading and underage MRDs in Lahore (Source: Author)

Figure 3: MR Overloading

Figure 4: Underage MRD

Figure 5: Underage MRD

Tahir et al. (2012) examined the epidemiology of road crashes attended by Rescue 1122 (an emergency ambulance and rescue service in Pakistan) in Lahore city during 2005–2010. The study revealed that rickshaws (MRs and ARs are not separately recorded) were involved in 22,488 road crashes, which comprised 18% of crashes attended by Rescue 1122 in Lahore. More recently, as part of his PhD program, the first author updated and extended this research in an unpublished report using Rescue 1122 crash data for 2011-2013. Rickshaws (both MRs and ARs) were involved in 51,992 road crashes in Punjab province in this period, with 15,735 of these occurring in Lahore. In order to better understand the high apparent involvement of these vehicles in crashes, this study examines the road safety behaviours and practices of MRDs that contribute to crashes.

Method

MRDs were observed at 30 approaches to 12 major signalised intersections in different areas of Lahore city, which is the second largest city in Pakistan, with a population of over 9 million (Ghaffar, 2015). Site selection criteria included: intersection and approaches with functional traffic signals; intersections with large numbers of MRs operating; observers' safety and convenience; and MR crash prone locations or proximity to crash locations (identified from Rescue 1122 data). The final selection was made following extensive inspection of possible sites by the first author. All 30 approaches to the 12 study intersections were located on major roads, and ranged from three to five lanes in width.

Two paper survey forms were developed to collect the data. The first form recorded site details and was completed once per site per session. A separate vehicle observation and MRD driving behaviours form was completed for each MRD. Observations were recorded for a full week (Monday to Sunday) in May 2015 between 9am and 7pm. The weather was clear, sunny and hot during the survey week. The piloting of the survey was conducted to inform its final structure and resulted in adding items regarding the number of signalized approaches and traffic lanes to the site details form, and new categories covering four items (goods carried, traffic lane use, colour of light when MR entered the intersection and movement prior to violation) to the vehicle and driver behaviours form.

The focus of the observation was on MRDs who were at the front of the traffic queue or at the rear, since these drivers were predominantly involved in traffic and road safety violations. MRs are officially motorcycles and therefore they are required by law to travel in the left lane along with other motorcycles and non-motorized vehicles. Observations were recorded in half-an-hour blocks (30 minutes on each approach) and after finishing one approach, the next approach was observed. MRD age and condition of MRs were judged from physical appearance, based on the experience of the first author. In Pakistan, all motorized vehicles must display registration plates on the front and rear. Whether at least one registration plate was visible was recorded for each MR. All data collection (piloting and full-scale survey) was carried out by the first author. The data from the paper survey forms were entered into Excel spreadsheets and then coded and analysed in SPSS version 22. Frequencies and percentages were calculated for all variables. To examine the association between different categorical variables cross-tabulation was performed by using Pearson's Chi-Square test (χ^2) with a significance level set at $p<0.05$. The results of the cross-tabulations and Chi-Square tests are presented below along with specific tables.

Results

In total 50 MRDs were observed in the pilot phase and 500 in the full-scale survey. Only the results of the full survey are presented below under three sub-headings covering temporal/location, vehicle, driver and driving behaviour characteristics.

Temporal/location characteristics

The largest number of MRDs (*n*=94) was observed at Grand Trunk (GT) Road near University of Engineering and Technology (UET), Lahore followed by Gadi Shahu Chowk ("chowk" means "intersection" in Urdu) (*n*=60), and Akbar Chowk and Boharwarwala Chowk (*n*=46) each. These approaches were located on major roads, having three to five lanes (i.e. GT Road). The highest number of observations by day was recorded on Monday (*n*=94), while the highest by time period was 225 for 9am to11am (Table 1).

Table 1: Temporal/location characteristics

No	Location	No of MRD observed	%		Day & Time	No of MRD observed	%
1	**GT Road, UET**	94	18.8		**Monday**	94	18.8
2	**Gadi Shahu Chowk**	60	12		**Tuesday**	80	16.0
3	**Akbar Chowk**	46	9.2		**Wednesday**	80	16.0
4	**Boharwala Chowk**	46	9.2		**Thursday**	60	12.0
5	**Yateem Khana Chowk**	40	8		**Friday**	72	14.4
6	**Kadak Nala**	36	7.2		**Saturday**	52	10.4
7	**Samanabad Chowk**	34	6.8		**Sunday**	62	12.4
8	**Railway Station**	32	6.4		**Total**	500	100
9	**New Campus**	32	6.4		**09:00am-11:00am**	225	45.0
10	**MAO College Chowk**	30	6		**11:01am-01:00pm**	146	29.2
11	**Scheme More**	30	6		**01:01pm-03:00pm**	12	2.4
12	**Moon Market**	20	4		**03.01pm-05:00pm**	80	16.0
	Total	500	100		**05.01pm-07:00pm**	37	7.4
					Total	500	100

During the survey process, a traffic warden was controlling traffic at four locations (Moon Market, MAO College, Samanabad and New Campus) and was absent at two locations (Kadak Nala and Akbar Chowk). At five other locations (Gadhi Shahu, Yateem Khana, GT Road, Boharwala Chowk and Scheme More) a traffic warden was present but was not controlling the traffic. At two locations (Railway Station and New Campus), a traffic warden arrived at some time during the observation period.

Vehicle Characteristics

Most MRs were in moderate (46.2%) or poor (45%) physical condition and only 8.8% were in good condition. All of the observed MRs had open chains; most (98.6%) had a motorcycle registration plate displayed on the front or back of the vehicle, 1.2% did not have any registration plate displayed and one appeared to have a fake number plate (Table 2).

Table 2: Vehicle characteristics

MR condition	N	%		MR overloading	N	%
Poor	225	45.0		***1-6***	247	49.4
Moderate	231	46.2		***7-10***	230	46.0
Good	44	8.8		***11-15***	23	4.6
Total	500	100		**Total**	500	100
Number plate display	**N**	**%**		**Type of passenger**	**N**	**%**
Yes	493	98.6		***Adults***	2734	86.2
No	6	1.2		***School- age children***	293	9.2
Other	1	.2		***Pre-school children***	145	4.6
Total	500	100		**Total**	3172	100

Most MRs (61.4%) were carrying only passengers, while (35.6%) were carrying some goods as well as passengers and (1.2%) carried a substantial amount of goods as well as passengers. About half (50.6%) of the MRs were carrying more than the nominal capacity of six passengers: 22.6% were carrying seven passengers, 13.8% had eight passengers, 13.2% had nine to twelve passengers and 1% were carrying 13 to 15 passengers. In total around 3,172 passengers were travelling on observed MRs (n=500), including 2,734 adults (86.2%), 293 school-age children (9.2%) and 145 pre-school children (4.6%) (Table 2). Chi-square tests were performed to determine the association between time of day and MR overloading. The results were not statistically significant [$\chi 2$ (1) = .728, p =.393]. Similarly, no significant difference was found between MR condition and number of passengers carried/MR overloading [$\chi 2$ (2) = .366, p =.833].

MRD Characteristics

Among the MRDs observed, 15.6% were possibly and 7.8% were judged to be clearly under the licensing age of 18 years. Almost a third (30.4%) of the MRDs appeared to be aged 31-40 years, and less than 2% of them were judged to be aged over 50 years (Table 3). There was a significant difference in the prevalence of underage MRDs across the various locations [$\chi 2$ (11) = 25.467, p <0.008]. Most underage MRDs (21.4%) were operating on GT Road, compared to (14.5%) in Township area and (11.1%) on Multan Road. Only 1% of under-aged MRDs were observed at Samanabad Chowk. Similarly, MRD aged ≥18 years were also more prevalent (18%) on GT Road compared to other areas (Gardi Shahu 11.7%, Boharwala Chowk 11%, Samanabad Chowk 8.6% etc.)

Table 3: MRD age groups in Lahore

Age group (year)	N	%
Possibly under 18	78	15.6
Clearly under 18	39	7.8
18-30	121	24.2
31-40	152	30.4
41-50	101	20.2
51-60	4	.8
Over 60	5	1.0
Total	500	100

MRD Driving Behaviours

The Table 4 below presents the driving behaviours of MRDs. It shows that only about 30% of MRs entered the intersection when the traffic signal was green. More than half (52.6%) of the MRDs entered the intersection when the traffic signal was red, and 17.4% entered when the signal was turning from yellow to green or red. Similarly, most MRDs (62%) found leaving before the light turned green (the 210 MRDs recorded as passing when the light was red or yellow turning to red) leaving too early or leaving after light turned red), so MR traffic conflicts[1] were observed in 62.8% of cases.

MR traffic conflicts most commonly involved motorized vehicles such as motorcycles 98 (19.6%), MRs 50 (10%), cars 12 (2.4%), van and AR 11 (2.2% each), truck 4(.8%) and multiple motorized vehicles 15 (3%). Likewise, conflicts were also observed with pedestrians 82 (16.4%) and non-motorized vehicles such as animal carts 11 (2.2%) and bicycles 3(.6%). One MR hit the rear of a van but there was no injury and only the van was damaged. The near miss collisions observed involved motorized vehicles (*n*=15) and pedestrians (*n*=5) that included adults, school children and female road users.

Table 4: MRD driving behaviours

Light colour when MR enters	N	%		Conflict observed	N	%
Red (violation)	263	52.6		***No***	185	37.0
Green (legal)	149	29.8		***Motorized vehicle***	180	36.0
Yellow turning Red (usually legal)	47	9.4		***Pedestrian***	82	16.4
Yellow turning Green (violation)	40	8.0		***Multiple motorized***	20	4.0
Unable to observe	1	0.2		***Pedestrian & Motorized***	19	3.8
Total	500	100		***Non-motorized***	10	2.0
				Motorized & non-motorized	2	0.4
Movement prior to violation				***Pedestrian & non-motorized***	1	0.2
No violation	189	37.8		***Unable to observe***	1	0.2
Fail to stop, enter on Red/late on Yellow	178	35.6		**Total**	50	10
Stationary, then enter before Green	132	26.4				
Total	500	100				

[1] A traffic conflict is a situation where two or more vehicles or a pedestrian approach each other in such a way that a crash may occur unless one of them applies an emergency manoeuvre [e.g. apply brakes, reducing speed, changing direction etc.] (Gledec, M. 1996)

Most MRDs (71.6%) were travelling in the middle traffic lane, while 18% were using the right lane and only 10.2% were in the left lane. No MRD was wearing a motorcycle helmet. In terms of other behaviours, 3.8% were using a mobile phone and less than 1% were smoking while driving.

Chi-square tests were performed to determine the association between MR conflicts and light colour, the results were statically significant [$\chi2$ (3) = 85.70, $p <0.001$]. The majority of MR conflicts with motorized, non-motorized vehicles and pedestrians (77%, 80% and 73.5% respectively) were observed at Red signals compared to Green (23%, 20% and 26.5% respectively).

Discussion

MRs are only registered as motorcycles and not as a specific vehicle type, so their exact number is unknown to authorities, however from the findings of previous studies and literature review (mainly newspaper articles), it appears that presently MRs are the largest informal paratransit mode in Pakistan. Most MRs observed in Lahore in the current study were not in good physical conditions, their repair and maintenance often seemed to be compromised. This may be a consequence of their low earning capacity (due to saturation of MRs on all routes) and lack of ownership by drivers as many MRDs do not own their vehicles and are working on daily wages. Modifications in design and compromised repair and maintenance conditions increase the likelihood of crashes.

About 23.4% of observed MRDs appeared to be younger than the minimum driver licensing age of 18 years in Pakistan. Given that police enforcement is higher in Lahore than elsewhere in Punjab, this could be predictive of an even worse situation in the smaller cities, towns and villages of Punjab, where minimal or no police enforcement exists. Data analysis shows that there was a significant difference in the prevalence of underage MRDs across the various locations [$\chi2$ (11) = 25.467, $p <0.008$]. Most underage MRDs (21.4%) were operating on GT Road, compared to (14.5%) in Township area and (11.1%) on Multan Road. These areas are characterised by high population density, poor levels of formal public transit, low socioeconomic status and low police enforcement, which could account for this figure. However, since 18.8% of MRDs in this study were observed on GT Road, the prevalence of underage MRDs does not represent a very large over-representation.

In addition to underage and unlicensed driving, MRDs do not have route permits and fixed routes, so they set up illegal terminals and encroach upon roads, footpaths and markets with a consequent contribution to traffic congestion, road crashes, air and noise pollution, and compromising the safety of pedestrians and other road users.

Most MRDs observed committed traffic violations such as entering on the red light or on yellow before the light had turned green, which in turn causes traffic conflicts and increases the likelihood of crashes. There is mixed traffic in Lahore, so MR traffic conflicts were observed with almost all kinds of motorized and non-motorized vehicles and other road-users (i.e. pedestrians). A reason cited for MR traffic conflicts is their frequent traffic-lane changing and overtaking, since they overtake anywhere and will even stop in the middle of the road to pick up passengers. It is worth noting that most MRDs were travelling in middle or right (high speed) lanes whereas they are required to travel in the left lane. Similarly, a few MRDs were using handheld mobile phones and smoking while driving, with these behaviours likely to increase the likelihood of crashes.

No MRDs wore helmets, although technically they are supposed to do so, because MRs are classed as motorcycles, and MRDs as motorcyclists have to wear helmets. However, AR riders do not have to wear a helmet, and the lack of any clear rules or guidelines for MR operation in Pakistan makes the classification of MRs, and hence the helmet requirement for MRDs, ambiguous. On the other hands, helmet wearing rates are very low even among motorcyclists, as is well-documented in previous studies in Pakistan (Ahmed, 2007; Hashmi et al., 2012; Hyder, Ghaffar, & Masood, 2000; Tahir et al., 2012, 2013).

Many MRs were overloaded, and this was frequently seen in those areas where there are minimal or no other public transport modes available. Overloading was also commonly observed in morning peak hours and on weekends. MR overloading could be attributed to economic pressure, as MRDs do not earn much and their incomes are decreasing, because of increasing MR numbers on almost all routes in Lahore. Another major reason for overloading is to meet passenger's needs; this is quite common in underprivileged areas, where family size is usually large and they cannot afford any other transport mode (e.g. taxi, AR, van etc.), so they prefer to travel together by MR, because it is cheaper (15-20 Rupees/trip/person) than other modes and offers some flexibility to accommodate extra passengers.

An important reason behind frequent violations of road safety and traffic rules by MRDs is weak or absent law enforcement. It was observed during the survey process that although traffic police were present at most of the locations, they were not controlling the traffic. Most of them were standing in a concealed spot or on corners to catch drivers (mainly motorcyclists) in order to fine them, and it appears that traffic management, deterrence or road safety awareness does not seem to be a priority. Some MRs did not have a motorcycle registration plate or were displaying a fake plate, yet they were not approached by police.

Although MRs were introduced in Pakistan (from Lahore) under the "President Employment Scheme" in 2001 (The Express Tribune, 2012), they still have only an informal status and are operating without any regulation. They are contributing to the road toll and endangering the safety of pedestrians and other road users. The haphazard growth and unregulated operation of MRs indicates the government's indifference towards the public transport sector in Pakistan. A few sporadic efforts have recently been made (introduction of a bus rapid transit system in Lahore and another between Rawalpindi and Islamabad), but overall there is a severe shortage of quality public transport facilities in Pakistan.

Road crashes and injuries have serious socioeconomic impacts on the individuals as well as on the national health care system and the economy. Existing transport infrastructure and facilities do not meet the needs of the rapidly growing population in Pakistan. Therefore, people are forced to use private transport and unsafe transport modes such as MRs. Increasing use of private transport modes and mushrooming of unregulated transport modes are resulting in high motorization rates, traffic congestion and road crashes. There is a need for government attention to improve public transport and road safety in Pakistan. An important element of this improvement is to devise an appropriate road safety and transport policy for MRs, so that the burden of road crashes involving these vehicles will be reduced.

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Restraining children with disabilities or medical conditions safely

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Abstract

In 2009, 288,300 children (7%) of those aged 0-14 years, were estimated to have a physical disability. Children with such conditions often cannot support their torso or head in an upright seated posture. They often have diverse conditions including seizures and intellectual disability.

The Australian Standard (AS/NZS 4370:2013) Restraint of Children with Disabilities, or Medical Conditions in Motor Vehicles recommends that these children be restrained in (AS/NZS 1754:2013) compliant car restraints. Even modified compliant car restraints should be considered before special purpose seats from overseas which are quite expensive and not compliant. Coupled with the recent release of Type G child restraints, and restraints with supportive side-impact protection that meet AS/NZS 1754:2013, Kidsafe Queensland has been extremely successful in seating increasing numbers of children with disabilities in Australian Standard child car restraints with minimal modifications.

Lessons learnt in Queensland provide a platform for strengthening the safe restraint of these children in motor vehicles in car restraints that meet one of the highest standards in the World. They also improve awareness and understanding of the ability to seat children with disabilities into compliant child car restraints.

We are collaborating with manufacturers on the development of car restraints that meet the requirements of children with disabilities and Australian Standards. We are also collaborating with occupational therapists, physiotherapists and other key stakeholders on the safest method of transporting children with medical conditions and their special needs.

Introduction

Children with disabilities can present many challenges in daily life and to seat them safely in motor vehicles has been a focus for Kidsafe Queensland. The release of the Australian Standard (AS/NZS 4370:2013) increased the impetus to restrain these children in compliant restraints and it supported the work that Kidsafe Queensland had been undertaking.

In Australia it is illegal to use child restraints which do not comply with the AS/NZS:1754 child restraint systems for use in motor vehicles. However, child restraints meeting this Standard are often not suitable for children with a disability or medical conditions and many special purpose child restraints are imported from overseas.

A study published in the Medical Journal of Australia (MJA) (Reene, Zuryinski, Elliot & Bilston, 2007) showed that:

- In Australia in 2005, 72 child passengers under the age of 16 were killed in motor vehicle accidents, accounting for about two-thirds of all road user deaths in this age group.
- About a thousand Australian children are seriously injured in motor vehicle accidents each year, despite 92% using seatbelts and child restraints.
- Car accidents are the most common cause of injury and deaths for Australian children aged 1-14 years and account for about 40% of all injury-related deaths.
- Premature graduation of children to adult seatbelts, misuse of seatbelts and use lap-only belts increase the risk of injury or death.
- Australian parents believe child restraint installation is easy, however research indicates that more than 20% of restraints are fitted incorrectly (e.g. top tether not connected, seatbelt incorrectly threaded or not buckled, anchorage point used incorrectly). About two-thirds of parents consider using licensed restraint-fitting stations.

Premature graduation of children to adult seatbelts is something commonly seen in the disability area. Parents are unaware that there are options for their children to stay within a 6-point harness for longer. When the incorrect restraint is used, whether because their age or physical needs, the increase in injury or death is much more significant, which is why Kidsafe Queensland is dedicated to providing the resources and education to help parents, occupational therapists and disability workers aware of other options for restraints in motor vehicles.

After investigation of many of the special purpose seats, Kidsafe Queensland staff were not happy with the weight, lack of tethers, adult seatbelt path and installation of many of these restraints.

The recent introduction of Type G seats particularly, has allowed Kidsafe staff to supply seats to Queensland families where there is a need for extra upper torso support and lateral supports. Previously it was common practice for families to import special-purpose seats at an incredibly expensive cost to themselves and/or the Queensland Government. The cost of imported speciality seats range from approximately $3000 to $15000. At one time they were the only option available even though not designed for Australian vehicles, roads and not legal under the Australian Standard. A complaint Type G seat allows a child to be restrained in a 6-point harness from approximately 6 months to 8 years or older. There are currently 5 Type G seats on the market, with more to be released. Prices vary between $250 and $480, making them more affordable for families. It also frees up any funding the families are entitled to for other vital needs. Not only does it help families financially, the seats are easily accessible which allows a variety of different seats to be tried for each individual case. All kids are different and disabilities are different, and having a myriad of seats to choose from allows for an optimal fit for each child’s special needs and also an optimal fit for the particular vehicle transporting each child. A seat may also need to be transferred between cars and special buses.

Along with Type G seats, the 2103 AS/NZS:1754 Standard also allowed manufactures to produce seats that can rear face for longer. The recently-released Type A4 restraint allows a child to rear face for between two and three years. In terms of disabilities, children who can’t support their own weight when sitting can often more easily be restrained rear-facing. It is safer for them to travel rear facing when their muscles cannot support the weight of their torso and head. Larger rear-facing seats have padded inserts that offer the body good, solid support which is often required. For the younger children and babies, Kidsafe Queensland is commonly using the Meridian SICT, which can rear face to approximately 2-3 years. It offers a great recline both rear facing and forward facing and has very supportive padding. It will also last approximately 4-6 years making it a great option financially. Having more options at a lower cost makes our work easier, lessens the stress on the families and also lessens the financial stress on the Government - which is often providing the funding for restraints for children with a disability or medical condition.

Kidsafe Queensland has had a 100% success rate in the past six months to June 2015 in seating children with disabilities in Australian Standard compliant child car restraints. Of 23 clients, 19 seats required some modification. This success is somewhat attributed to the questionnaire developed by Kidsafe Queensland and the enthusiasm from the specialised medical practitioners by providing vital information to allow us to assess each child's individual need. The team at Rehabilitation Engineering at Lady Cilento Children's Hospital and other orthopaedic departments throughout Queensland hospitals are embracing the use of compliant seats and work closely with us to provide input and modifications where required.

To date 11 training seminars have been delivered with various organisations and hospital Occupational Therapists and Physiotherapists on the use of compliant seats. Seminars have also been delivered to the Cerebral Palsy League workers, Department of Child Safety Officers and Disability Services workers.

Case Studies

Child A. Condition - Down Syndrome with sternal sutures following open heart surgery; scoliosis with thoracic spine concave to the left centred at T6.

Child A was very difficult to transport in the car due to behavioural issues which included getting out of his child restraint and trying to climb into the front seats whilst parents were driving. Child A used to scream, bite and hit when the harness was being done up. His parents and OT worked out that the chest area was still very tender and was causing this behaviour. Child A also needed some extra lateral support to help with the curve of his spine.

After trialling Child A in three seats over half-hour time periods, The Maxi Guard SICT with modifications was the most successful.

Modifications included the design and build of a chest plate to cover the area which caused him to be distressed. Prototype 1 was made it out of neoprene with a white foam backing but after fitting this was found to be bulky and, with the Queensland humidity, it was not viable. Trial 2 used a heavy wetsuit material with a small pocket along the sternum for extra support and connected it onto the crotch area so it was secure and firm.

A high-density foam wedge was added to the left hand side of the seat to get child A seated more frontal than curved.

A Houdini Stop strap was added to discourage Child A removing his arms from the harness.

It has been four months since completion of the modifications and supply of the seat and the parents are extremely happy with the outcome. Child A is now staying in his restraint and is happy to get in his restraint, making travelling in the car pleasant for all.

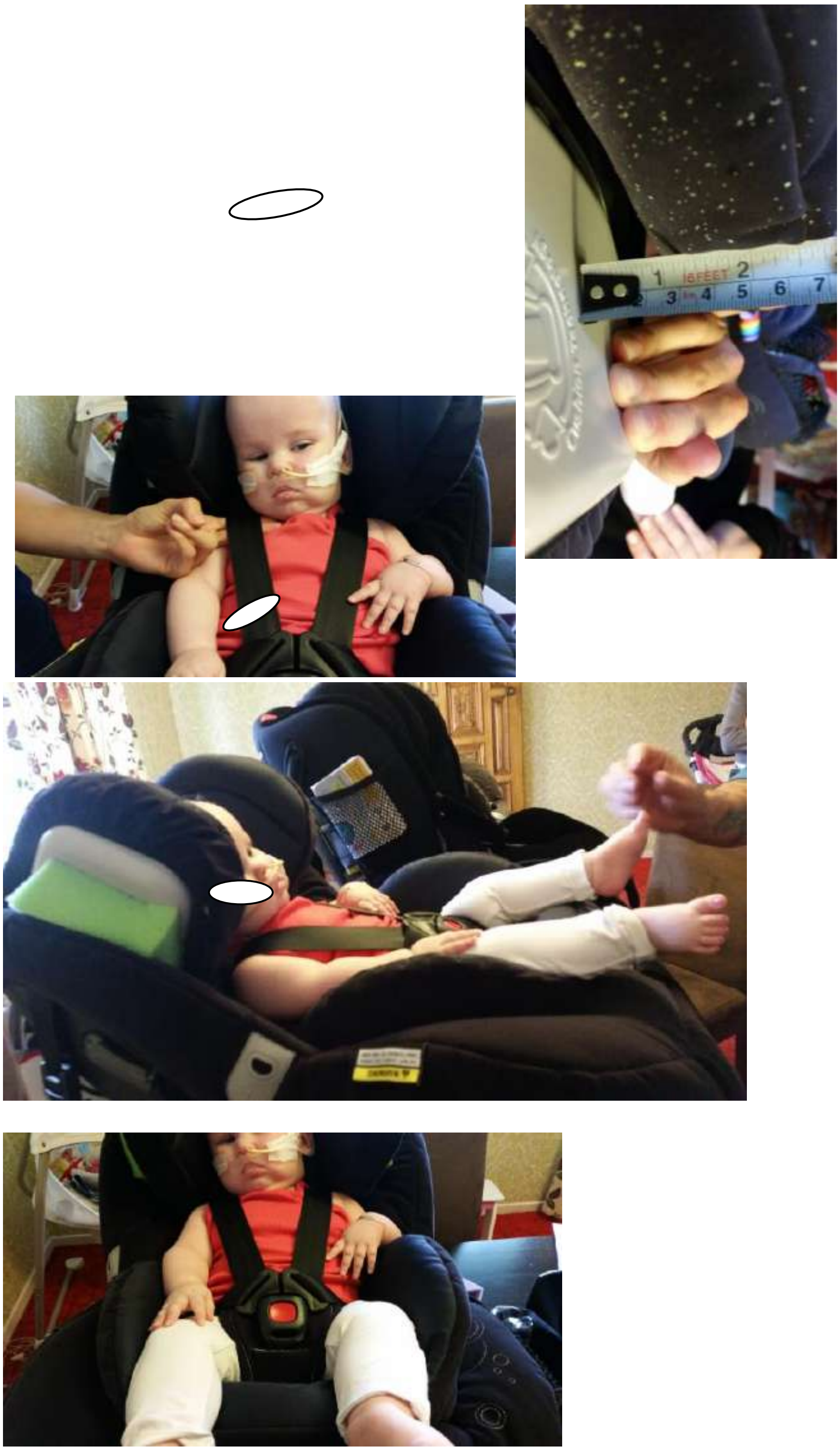
Child B. Condition: Very low tone; nil head control; not always alert; frequent seizure activity (up to 40 per day); requires oxygen through NP; NGT feeds; and under palliative care.

Child A, due to such frequent seizures, and not having a restraint that supported her enough whilst travelling, was only transport via ambulance to and from hospital appointments.

After trialling Child B in three seats over one-hour time slots to monitor how she functioned in the child restraints while seizing, Kidsafe Queensland staff we able to work out areas within the restraint where extra padding was required. The Meridian SICT with modifications was the most successful solution.

Modifications included using high density foam wedges in places where Child B needed extra support. We also added a high-density foam wedge in the head area to compress the head support to open the area for support to the head whilst seizures occurred while allowing enough room for sufficient airflow. Child B was in full recline in rear-facing mode.

It has been two months since completion of the modifications and supply of the restraint and the parents are extremely happy with the outcome as Child B is travelling comfortably rearward facing to and from hospital.



Child C. Condition: Cerebral palsy.

Child C was only being transported via the special school bus but, the bus company then refused to transport Child C due to the seizures and postural position which was causing unsafe driver decisions. This forced the school to review Child C's options for transportation.

After trialling Child C in four seats over half-hour time slots, the Maxi Guard SICT with modifications was the most successful.

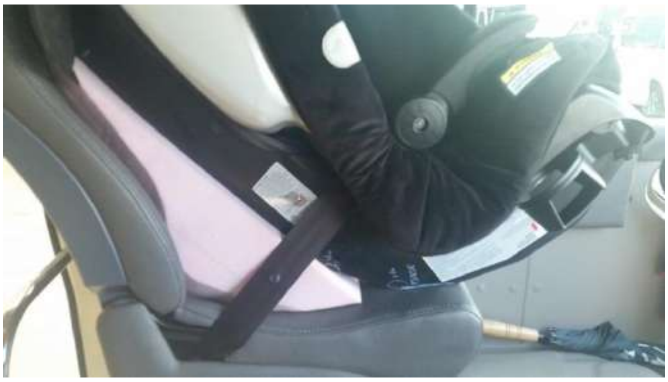
Modifications included removal of the recline foot and the design and build of a new recline shell in high-density foam in three layers. This was built with help from the rehabilitation engineers at Lady Cilento Children's Hospital. This process involved many hours and templates to create the exact recline necessary for the bus seat.

We also added a high-density foam head support that inserted into the head area of the restraint to support the head as Child C would not and could not lean back into the seat due to her condition – therefore we had to bring the seat to her. A child's neck brace also used to support the head further – keeping her chin from resting on her chest – thereby keeping Child C's airway open. A Secure-Ap was added to give even more lateral support in the harness.

It has been four months since modifications were completed and supply of the seat and the school are extremely happy with the outcome as Child C is again being transported to and from school in the bus. The driver is no longer having to pull over repeatedly to prop child C back up in her seat.







Discussions

Kidsafe Queensland is engaging with and consulting key stakeholders including the three child car restraint manufacturers in Australia – Britax, Dorel and Infa-secure. Some manufacturers provide extended crotch buckles and advice on modifications of their child car restraints. We are also in consultation with Kidsafe in Australian Capital Territory and Western Australia. Both of these states also provide solutions for children with disability and/or medical conditions. We also consult with medical practitioners and occupational therapist and various relevant others on the needs for children with a disability or medical condition. Kidsafe Queensland has provided child car restraints for children with hip spica plasters for many years but, with the introduction of the new standard for child car restraints, the high seat sides giving extra side-impact protection, means that these seats are difficult to use with for babies and children with hip spica plasters. Consultation with the manufacturers, and the new compliant seats being brought to market, has resulted in new seating options for these conditions.

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Safer transport for a safer community – development and implementation of the Gold Coast Road Safety Plan 2015-2020

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Abstract

The City of Gold manages over 3,000km of local roads and more than 2,000km of footpaths within the City. To ensure the provision of a safe and functional environment for all road users, the Gold Coast Road Safety Plan 2015-2020 (GCRSP) was developed, as foreshadowed in the Gold Coast City Transport Strategy 2031.

A collaborative approach underpinned the Plan's development in an effort to maximise partner capabilities and recognise inclusive, holistic approaches are more efficient and effective.

The GCRSP was adopted by the Council of the City of Gold Coast on 2 April 2015, and seeks to achieve a 30% reduction in the number of serious injuries and fatalities associated with road trauma from 2010 to 2020. The Plan provides a local framework for the City to improve the safety of the transport system it owns and manages along with appropriate support for its road users. It takes into consideration our transport infrastructure, its users and the unique geographical and demographic features of the Gold Coast.

This Plan consolidates existing action, integrates complementary use of resources and identifies innovative approaches to deliver a coordinated, collaborative road safety effort. It essentially represents a "checklist" of concepts tailored to address local road safety challenges, without the need for significant levels of investment.

This paper provides a broad overview of the GCRSP, as well as outlining the evidence-based and collaborative approach to prepare the Plan, focusing on opportunities and challenges experienced throughout the Plan's development.

Overview

The Gold Coast City Transport Strategy 2031 was released by the Council of City of Gold Coast in March 2013. The Strategy broadly recognises the importance of providing a safe and functional environment for all road users (including drivers, passengers, motorcyclists, pedestrians, cyclists and public transport users) and highlights a commitment to establishing a Road Safety Plan for the City.

The development of the Gold Coast Road Safety Plan 2015-2020 (GCRSP) stems from this overarching City Transport Strategy and is part of the City's effort to provide the safest and most efficient transport system possible.

A partnership approach was central to development of the GCRSP, utilising the capabilities of each stakeholder organisation and recognising that a holistic, collaborative approach to road safety has the greatest chance for successful outcomes. The development of the GCRSP involved a number of stakeholder organisations including:

- City of Gold Coast
- Department of Transport and Main Roads
- Queensland Police Service
- Royal Automobile Club of Queensland (RACQ)
- Centre for Accident Research & Road Safety – Queensland (CARRS-Q)

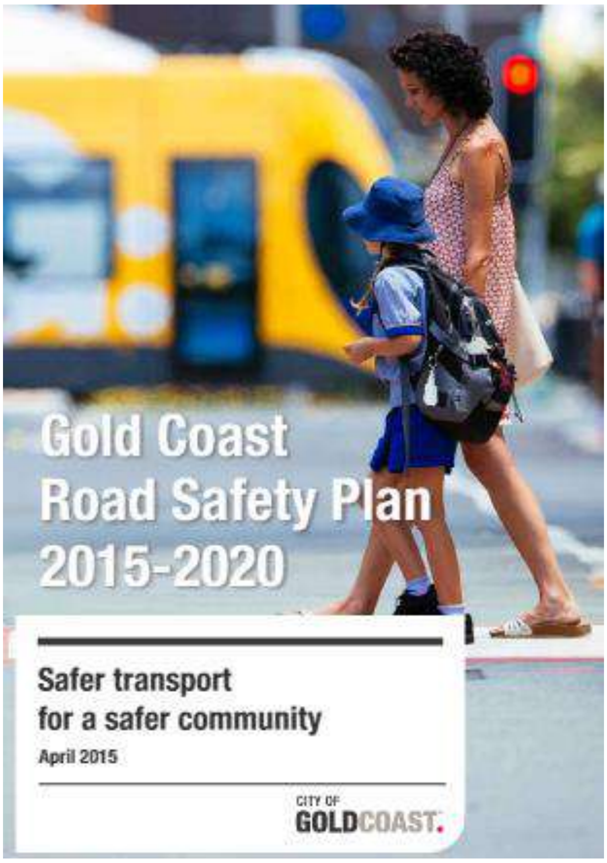

Figure 1. Gold Coast Road Safety Plan Cover Page

To inform the road safety plan development, crash statistics and trends for the ten year period from 2003-2012 were analysed to identify specific categories and sub-categories of causal and contributing factors, demographics, seasonality and geographic influences on crash locations and types. Literature reviews were then undertaken to identify the most effective countermeasures to address the identified issues as well as understand the implications of future changes to the regions transport network and population.

Findings were consolidated into 20 focus areas, which represented a distinct category of local issues and/or trends. A key criterion for issue inclusion was the domain of stakeholders influence to enable a solution at a targeted local level. This helped shape the development of a localised ‘Safe System’ approach consisting of four themes and aspirations relating to our road safety context; our people, our transport system, our places and our shared responsibility.

Figure 2. Our 'Safe System' approach

In total, there are 58 actions proposed within the Plan, with lead / support responsibilities identified and broad timeframes for action (short/medium/long). As seen in Table 1 below, each action is presented in clear and concise language, with a target timeframe to undertake the action and organisation responsible for implementation of the action also identified.

Table 1. Example of Actions within the GCRSP

No.	Action	Timeframe	Lead/partners
2.11	Develop a strategic view of speed limits with the priority aim of delivering safer road environments for all users: • investigate increased implementation of the 50 kilometre per hour urban default speed limit in existing 60 kilometre per hour signed roads • investigate and implement lower speed limits (for example, 30 or 40 kilometres per hour) at locations of pedestrian priority and during times of high pedestrian activity.	Short - medium	City TMR QPS
2.12	Investigate and trial temporary speed zones in beachfront entertainment precincts and other locations with high numbers of pedestrian users (e.g. 40 kilometres per hour in Surfers Paradise and Broadbeach on Friday and Saturday nights between 8pm and 5am).	Short - medium	City TMR QPS

The actions where the City has lead responsibility have been purposely worded to reflect the City's existing responsibilities for improving road safety in a roadmap for success. The role of the Road Safety Plan is to coalesce existing actions with future actions to ensure meaningful outcomes.

A partnership approach augmented the Plan's development in an effort to maximise partner capabilities and recognise that inclusive, holistic approaches are more efficient and effective than efforts in isolation. This approach has tangibly translated into stronger inter-agency relationships and an effective governance transition from the GCRSP development to action implementation phase.

Planning process

A best practice and transferable methodology was adopted to develop the GCRSP, with four distinct stages:

Stage 1: Initiation

- Defining the purpose and scope underpinned by justification to invest
- Developing the terms of reference and establishing the appropriate governance structure
- Obtaining buy-in to the intended project from respective agency "decision-makers" prior to formal project commencement (via an Executive Steering Committee)

Stage 2: Project planning and implementation

- Developing a collaborative approach with stakeholders through a series of workshops to establish agreement and commitment to tangible project objectives (via a Partnership Advisory Group)
- Identifying a planning framework suitable to the local Gold Coast context
- Establishing an agreed vision for high level targets in the context of State, National and International Road Safety Planning
- Evaluating historic, existing and future road safety data and trends
- Identifying contemporary road safety strategic policies and actions to address key issues
- Communicating an initial draft Road Safety Plan technical document suitable for targeted stakeholder engagement via the established project governance framework

Stage 3: Project delivery

- Translating the RSP technical document into an intended community-facing draft plan for consultation and final refinement with key stakeholders
- Engaging internal and external stakeholders to gain "formal" endorsement and support for the plan
- Formal adoption of the Plan as policy by the Council of the City of Gold Coast

Stage 4: Project closure and evaluation

- Public launch of the plan (officially launched in May 2015)
- Undertaking a post-development review to highlight planning successes and document lessons learned
- Transitioning from development of the GCRSP into implementation and monitoring
- Immediately mobilising with partners to establish "year 1" deliverables to maintain positive momentum achieved via the GCRSP launch

Lessons Learned

Lessons learned throughout the Plan's development focus on opportunities for other local governments in relation to a subject matter (road safety) that is often regarded to be a matter for Federal or State Government to address. Rather than replicating the national and state agenda, a locally-focused technical investigation was undertaken to understand the issues experienced within the unique regional features of the Gold Coast – transport system, economy, geography, demography etc. This allowed actions to be tailored to the local context, whilst contributing to the higher order objectives of the State. For example, this enables the Gold Coast beachfront precincts to utilise a different approach to road safety than those adopted in our hinterland region. Another key local example is the challenge regarding tailoring road safety actions for the large proportion of transient population in the City – visitors, international students etc.

The GCRSP is one of several transport network plans that cascade from the overarching Gold Coast City Transport Strategy released in 2013. Learnings and successful elements of the road safety planning process will be applied and refined when developing subsequent network plans –project management & delivery learnings, as well as technical symbiosis between the multi-modal planning framework.

Next Steps: Implementation and Evaluation

The GCRSP sets a clear direction for improved road safety within the City over the next five years. With several short-term actions within the plan currently in the early stages of implementation, the development of the Road Safety Plan significantly increased awareness of the City's role in road safety with key local stakeholders. Following the Plan's endorsement in April 2015, there has been a noticeable increase in public-facing road safety messaging about GCRSP (and partner) initiatives. The Mayor has actively participated in recent Road Safety events such as Fatality Free Friday and is due to launch the City's 'Drive Safe' Community Speed Awareness initiative in early August 2015.

The strong support for the GCRSP from key City stakeholders has provided a clear mandate for the City's Transport & Traffic Branch to immediately implement the intended short-term actions within the Plan. Several initiatives commenced in late 2014/15 allowed the Partnership Advisory Group to provide direction to the respective projects and ensure that the positive momentum from the Plan development phase was immediately transferred into the Plan implementation phase.

The Plan also highlights monitoring and evaluation as a key component of implementation. One of the Plan's actions is to establish fit-for-purpose monitoring and evaluation tools to ensure that Road Safety Plan actions successfully mitigate local road safety issues and emerging trends. An intended (and fit-for-purpose) evaluation methodology is due to be presented to the Gold Coast Road Safety Partnership Advisory Group for endorsement in late 2015.

The ongoing implementation of outcome-focused actions that have the intention of reducing serious road trauma in the City, as presented in the Plan, will result in positive outcomes which are likely to have cumulative community benefits beyond 2020.

A copy of the Gold Coast Road Safety Plan 2015 – 2020 can be viewed and downloaded at http://www.goldcoast.qld.gov.au/documents/bf/gc-road-safety-plan.pdf.

To Serve and Be Protected:

Combining Road Safety with Work Health and Safety

Sen Sgt Michael Timms

NSW Police Force

Abstract

For decades, road safety 101 has been founded on the principle of deterrence and the presence of marked police cars parked in static locations on the road network.

In 2012, NSW Police Force reimagined this principle by strategically deploying state-of-the-art Highway Patrol vehicles on the freeway network in and around Sydney for Operation Freeflow. This route-specific approach and the new Highway Patrol fleet's high-visibility marking package and suite of road policing technology now extends to other highways throughout the state.

The police patrolling Sydney's "M" roads seek to do more than deter crashes on these vital corridors. These Highway Patrol members double as a rapid deployment force, clearing the road of minor crashes and breakdowns, and taking charge of major incidents so that the road network can be returned to full capacity as soon as possible.

But what happens when road safety collides with work health and safety? WHS legislation imposes a duty upon employers to eliminate or at the very least, reduce risks to workers.

Traffic and Highway Patrol Command had to face this question in 2014-15 and carry out a safety review of Operation Freeflow following a crash where a semi-trailer careening across a centre median not far from where a Highway Patrol car had earlier been tasked.

Can police deliver road safety strategies that protect the public without exposing officers to unnecessary risks? This paper show how it is possible and asks what other agencies such as road authorities can do to assist police.

Introduction

The New South Wales Government's NSW2021 plan is "the NSW Government's strategic business plan, setting priorities for action and guiding resource allocation" (https://www.nsw.gov.au/sites/default/files/nsw_2021_plan.pdf). NSW2021 contains goals related to all areas of governmental administration including transport.
Within the area of roads and road safety, two goals are of particular significance:

Goal 7 Reduce Travel Times

Goal 10 Improve Road Safety

New South Wales Police Force (NSWPF) has legislated responsibility for public safety by virtue of the Police Act 1990. Changes to the structure of the force in late 2011 saw the creation of Traffic and Highway Patrol Command (THPC) which brought all Highway Patrol officers under the direct command of an Assistant Commissioner along with state resources such as the Crash Investigation Unit, Joint Traffic Task Force, VIP Escort Unit and the Random Drug Testing Unit.
The restructure enabled THPC to task and deploy based on emerging road trauma trends and local intelligence. Highway Patrol officers are no longer deployed based on lines arbitrarily

drawn on a map but can be strategically positioned, for example, to provide route-specific coverage on state highways.
In 2011, new work health and safety (WHS) legislation was introduced in NSW based on a national model. Replacing OH&S, the new legislation, codes of practice and safety management systems place personal responsibility on workers and senior managers (referred to in legislation as “officers”) to ensure the safety of people at work including their own staff and visitors. For an organisation such as NSWPF, the definition of visitors includes people in custody and motorists under the direction of police at an incident or planned activity such as random breath testing location.

Operation Freeflow

Maintaining the free flow of traffic has long been a primary objective of the Highway Patrol in NSW. During the 1980’s, officers based in metropolitan Sydney were tasked to patrol clearways each morning and afternoon to ensure that lanes were clear and that vehicles parked in clearways were towed and received a parking fine.
In the past 20-30 years, the freeway network around Sydney has expanded and roads stretching from Newcastle, Central Coast and the Illawarra are now commuter corridors used by tens of thousands of vehicles each day. Weekends offer no respite from heavy traffic as evidenced by the introduction of clearways on selected Sydney roads in 2014.
The impact of even minor incidents such as breakdowns and nose-to-tail collisions on the network can generate lengthy delays if not quickly sidelined. A major crash, particularly a protracted incident involving a heavy vehicle can result in the morning or afternoon peak being “lost”, meaning the traffic flow won’t recover.
Supported by Transport for NSW, Operation Freeflow commenced in March 2012 and involves the strategic placement of Highway Patrol vehicles throughout “M” roads in the Sydney metropolitan area and beyond. These motorways are the M2, M4, M5/Hume Highway and M7 in Sydney, the M1 (formerly the F3) to Newcastle and the Princes Hwy/Mt Ousley Rd/M1 (formerly the F6) to Albion Park in the Illawarra.
Those motorways are dissected into sixteen sectors with each sector assigned AM and PM shift officers to patrol between 5am to 7pm each Monday to Friday. In total 32 police are deployed to Freefow duties each weekday. A reduced service is provided on weekends.
At the commencement of their shift, police notify the Police Liaison Officer (PLO) at the Transport Management Centre (TMC). The PLO is a Senior Sergeant experienced in road policing and acting under the authority of the Superintendent, Traffic Operations Management, also based at the TMC. The PLO works with TMC staff to ensure that incidents are responded to and cleared as quickly as possible.
Freeflow cars attending incidents as initial responders are backed by the TMC who can call upon resources including traffic commanders, response crews, cranes, heavy tow trucks and other recovery equipment to achieve the goal of returning the road to normal operating conditions.
The *Commander’s Intent* or objectives of Operation Freelow are:

- Deter excessive speeding, thus reducing the incidence and severity of speed related crashes
- Deter breaches of current road transport legislation and encourage the free flow of traffic
- Actively monitor heavy vehicle movement and encourage driver safety
- Act as a first response/assessment vehicle
- Provide accurate, real time intelligence to the Transport Management Centre.

Operation Freeflow is a key part of the NSWPF response to NSW2021. That response includes the establishment of THPC Motorcycle Response Teams in Sydney City and the Parramatta CBD. These Highway Patrol motorcyclists patrol the downtown areas of those cities including the vital harbour crossings. Freeflow-style operations are also carried out daily on the Hume and Pacific Highways and on other state highways during long weekends. The pre-deployment of police resources to the motorways is consistent with today's terror threat. The Australian government has acknowledged that "transport systems continue to be attractive targets for terrorists seeking to inflict mass casualties, economic damage, instil fear and create spectacular media imagery" and the Department of Infrastructure and Regional Development include roads as a part of the transport system under threat. (https://www.infrastructure.gov.au/transport/security/).
In the case of Sydney's Lindt Cafe siege in December 2014, the first police officer on the scene was from the Motorcycle Response Team.

Freeflow Taskings

During their shift, Operation Freeflow crews carry out mobile and static patrols of their assigned sectors. Mobile patrols enable Freeflow vehicles to check traffic for any delays caused by breakdowns and minor crashes. The police radio is monitored and officers are usually listening to commercial radio traffic reports.
It has long been argued that the presence of a marked police vehicle parked by the side of the road is an effective road safety strategy.
*Stationary enforcement, such as a visible marked Police car, has a direct and local effect on traffic speed. (*Cameron et al, Page 2, 2003)
The National Roads and Motorists Association (NRMA) said as recently as March 2015 that "we strongly believe that a visible police presence is the most effective way to encourage positive changes in driver behaviour".
http://www.mynrma.com.au/media/NRMA_plan_for_fairer_mobile_speed_cameras.pdf
Highway Patrol marked sedans feature striking "high-vis" markings and roof mounted lights with message bar for approaching motorists. The marking package has since been replicated on motorcycles and the random drug & breath testing bus commissioned for the Christmas-New Year campaign 2014-15.
The marked highway patrol vehicles of today are much more striking than the police cars Cameron was referring to, which would have been fortunate to have two revolving beacons of poor quality with modest "Police" livery. The benefits from stationary taskings using current highway patrol marked vehicles have been enhanced, hence the support of the NRMA.
The locations of high profile static Freeflow taskings include centre median or cross over points on freeways as well as emergency phone bays on the sides of roads where police can be separated from the running lanes.
Given the high speed limits on these roads, any vehicle interceptions are conducted as a mobile traffic stop. This involves police following target vehicles, activating warning devices and pulling them over to the side of the road with the police vehicle flashing lights and presence offering protection from passing traffic.

The Hume Highway Truck Crash

On 21 July 2014, the driver of a semi-trailer travelling south on the Hume Highway, Ingleburn suffered a medical episode which resulted in the truck departing the roadway, careening through the grassed median strip and into the path of traffic on the northbound

carriageway. A collision subsequently occurred with a northbound semi-trailer and debris was scattered over a large area. Traffic was disrupted for several hours.
Figure 1 below, taken from a Police helicopter, shows the crash site. The wheel tracks made by the truck at fault can be seen bottom of photo. That vehicle can be seen where it came to rest on the road. The truck that has come to rest in the median was the northbound vehicle.
Shortly before the crash, a Highway Patrol vehicle had been parked in the median strip of the Hume Highway at Ingleburn performing a stationary tasking for Operation Freeflow. This tasking was close to where the crash occurred. The Highway Patrol officer had moved off to intercept a southbound unregistered vehicle. In the aftermath of the crash, the Highway Patrol officer flagged concerns about the incident with their local supervisor.

Figure's 1 & 2: Aftermath of the Hume Highway Crash

Photographs: NSWPF Police Aviation Support Branch

The NSWPF injury recording system has provision to record "near miss" events. This event was recorded as a near miss and a wider investigation began involving the THPC Work Health and Safety Officer. Established in 2014, the WHS officer provides advice to the head of profession on safety issues.
The WHS legislation and departmental policies place an obligation on "the officer'" to eliminate or reduce risks to workers in the workplace. A review of static taskings in median strips for Operation Freeflow and similar enforcement throughout the state was triggered.

Managing risks to workers

The hierarchy of controls for risk management holds that risks should be eliminated or effective controls implemented. But how does this work for road policing?
According to the Centre for Road Safety, speeding contributes to 40% of fatal crashes http://roadsafety.transport.nsw.gov.au/speeding/index.html. However, reducing the freeway speed limit to 40km/h so that police could undertake speed enforcement more safely is unlikely to be considered a reasonable way to control risks.
The SafeWork Australia Code of Practice "How to Manage Work Health and Safety Risks" (2011) provides practical guidance for the management of work health and safety risks. Codes of practice are admissible in court proceedings under the WHS Act and Regulations.
The code of practice identifies four steps in risk management:

- **identify hazards** – find out what could cause harm
- **assess risks** if necessary – understand the nature of the harm that could be caused by the hazard, how serious the harm could be and the likelihood of it happening

- **control risks** – implement the most effective control measure that is reasonably practicable in the circumstances
- **review control measures** to ensure they are working as planned.

Identify hazards
Working on roads has risks and NSWPF as well as other *persons conducting business undertakings* or PCBU's as they are referred to in the WHS legislation, must manage those risks. The term PCBU includes people, companies, organisations and government departments.
The Highway Patrol officers identified that police parked in certain locations might be hit by runaway vehicles. It was noted that the truck driver in the Hume Highway was believed to have already been deceased when he departed the road. The hazard of a collision with an out of control vehicle was the risk identified in this matter and became the basis for the risk assessment that would follow.
Assess risks
At the direction of *the officer*, the THPC WHS officer began a corporate risk assessment and review of road policing activities where Highway Patrol vehicles are parked on median strips and other areas adjacent to running lanes such as breakdown lanes. A risk assessment team and working party were formed.
Consultation with affected workers is a legislative requirement of the WHS legislation, so the "median strip working party" comprised of experienced highway patrol members including the police who raised the concerns, and elected delegates of the Police Association of NSW. The formation of small working parties has since been used for other road policing WHS issues including the impact of daytime running lights on Highway Patrol vehicles.
In establishing the context of crash risk for stationary enforcement on median strips, Centre for Road Safety data (Road Traffic Crashes in New South Wales 2013) indicates that only 3% of fatal and injury crashes occur on dual carriageway (freeway) road types (page 45) confirming that they are the safest class of road. Vehicles departing the road to the right represent 4.6% of crashes on all NSW roads, compared to 10.7% of crashes where vehicles leave the road to the left (page 27) which presented no heighted risk for median strips.
Risk assessment tools including the NSWPF safety management system (SMS) use a risk rating matrix which examines the consequences of a given risk and compares it against the likelihood of an incident occurring. Once the consequence and likelihood are determined, an overall risk rating raging from A-D is applied with A being the highest risk and D presenting the lowest level of residual risk.
The consequences of a runaway heavy vehicle driving into a parked police could range from major injuries to the death of an officer. The consequence rating on the NSWPF risk matrix had to be rated at "C4 Critical". However it is an uncommon occurrence and rated at "L3 Unlikely" or "once every 10 years" on the matrix. This equated to an overall rating of "C". Whilst such an overall rating did not predicate that further action be taken, the working party recommended several measures.
Control risks
The hierarchy of risk controls asks if is possible to eliminate the hazard all together:
It may not be possible to eliminate a hazard if doing so means that you cannot make the end product or deliver the service. If you cannot eliminate the hazard, then eliminate as many of the risks associated with the hazard as possible.
SafeWork Australia Code of Practice "How to Manage Work Health and Safety Risks" (2011, P14)".
In this case, the end product or service is the delivery of NSW2021 Goals 7 and 10. The NSW2021 Performance Report 2014-15, published as part of the state budget papers reported

on how NSW government departments are meeting the goals set in NSW2021. Positive trends were reported in three key areas directly relating to Operation Freeflow.
Firstly, the average clearance time for unplanned incidents on principle routes including motorways had fallen from a (2011) baseline of 39.98 minutes to 37.67 minutes in 2014-15.
Secondly, the number of major incidents that take longer than four hours to clear was reported to have fallen from a baseline of thirteen (13) per year to seven (7) in 2013-14.
Thirdly, the target of 4.3 deaths per 100,000 to be achieved by 2016 was well on track to be met and indeed "NSW recorded a fatality rate of 4.1 per 100,000 population in 2014, down from 4.5 the previous year and the lowest fatality rate for NSW since records began in 1908". http://www.transport.nsw.gov.au/media-releases/2014-road-toll-figures-released-record-low-more-do
With initiatives such as Operation Freeflow at the forefront of the delivery of these goals, it is imperative that providing that service continue.
The risk assessment identified a number of existing controls that were already being applied when working in median strips. Stationary enforcement duties are conducted with Highway Patrol vehicles featuring a "hi-vis" marking package as part of high profile road safety operations. The phase-in of this marking package has coincided with two consecutive years of record low NSW road tolls. Another *safer vehicles* control is that Highway Patrol vehicles also cannot be selected for service unless they have attained a five star ANCAP crash rating.
Highway Patrol vehicles perform stationary taskings where there is a good line of sight to approaching or departing traffic. This is a long standing practice due to the legal requirements of obtaining a valid radar or laser speed check. The direction in which they face is determined based on the availability of egress to the running lanes and road infrastructure such as wire rope barriers or armco railing. This is illustrated in Figure 3 below. The roof-mounted variable message bar can be programmed to display road safety or advisory messages for vehicles approaching from the rear.
When performing static duties, officers wear their seat belt except when they are out of their vehicles in which case their approved reflective vest is worn.

Figure's 3 and 4 – Operation Freeflow Static Taskings

Photograph: Sonia Roberts

In addition to turning to road safety data to quantify the likelihood of crashes that could impact on stationary highway patrol vehicles parked in medians, road safety was able to provide guidance when parking to the left of the running lanes.
In 2012, Transport for NSW convened the break down lane safety working group to look at safety issues surrounding break down lanes. The THPC WHS officer represented NSWPF on

that working party that supported breakdown lanes being a minimum of three metres wide.
In addition, communications messaging to stranded motorists that they should look for a safe place to pull over was reinforced with highway patrol supervisors and staff. Photograph 4 above shows an emergency phone bay with a suitably wide breakdown lane.
The median strip working party also sought to allay any concerns of individual members by conducting a field audit of static tasking locations. Region highway patrol commanders were assigned responsibility for carrying out site inspections in their areas. The methodology for those inspections was adapted from one already used for stationary random breath testing to identify elevated risks associated with the design of individual static sites.
That process resulted in a small number of static sites being abandoned in favour of alternative sites nominated by highway patrol officers.

Review control measures

Following the completion of the working party, a review process was initiated. This included field inspections and audits component by Highway Patrol Senior Sergeants. Existing NSWPF SMS safety observation procedures are employed for these inspections which are also undertaken by the WHS officer and senior commander's including the Assistant Commissioner THPC.
In late 2014, a complaint was made to WorkCover NSW claiming that a highway patrol vehicle in northern NSW was parked in a "dangerous" position and that NSWPF should be investigated for breaches of the WHS legislation.
The THPC WHS officer provided advice to WorkCover regarding the median strip working party process and outcomes. The site in question featured a wide centre median that offered protection to the stationary police vehicle from the rear in the form of wire rope barrier and front protection from a concrete barrier from a nearby bridge. Based on the information provided by THPC, WorkCover declined to investigate the matter further.
With a number of major road projects scheduled to commence in 2015, site selection may need further review should road construction and narrow lane widths impact on safety.
Figure 5 below depicts narrowed lanes during the widening of the M5 motorway in south west Sydney in 2014-5. Static taskings on the median or side of the road on this section of road in the photo would not be possible.

Figure 5 – Changed traffic conditions

Photograph: Sonia Roberts

The role of roads agencies

WHS safety management systems contain various "elements" not dissimilar to the safe systems approach to road safety and its "pillars". Road agencies plan, build and construct *safer roads* which are used by the public as well as workers like police, maintenance crews and tow truck operators (safer people).

When selecting a suitable site for random breath and roadside drug testing, police are able to use their own vehicles as well as traffic cones to implement a layout that reduces the speeds of passing traffic and provides a safer working environment. This is depicted in Figure 6 below, a stationary testing site on Campbelltown Road, Campbelltown over the 2015 June long weekend.

Figure 6 – Stationary Testing Site

Photograph: Sonia Roberts

For speed detection and activities on freeways such Operation Freeflow, police need to make use of infrastructure that has been built in to the road. Freeflow and related operations throughout NSW make a significant contribution towards NSW2021. Consultation with law enforcement in road design phase to establish areas where police can park safety and provide high-visibility static taskings could make a contribution towards both work health and safety and road safety.

Areas such as contraflow cross over points in median strips could be constructed with concrete enforcement pads, surrounded by protective structures to reduce the likelihood of a police vehicle being struck, or at least reducing the severity of such an impact. Multiple pads are required to as to ensure enforcement does not become predictable.

Static locations already in use need to be proactively maintained and kept free of debris that can easily cause a puncture to a highway patrol vehicles low profile tyres.

Vehicles involved in minor collisions often need to be shepherded off the running lanes by police or RMS road crews. Even then, traffic flow is unlikely to fully recover until all the vehicles, tow trucks, flashing lights etc are gone. The risks of secondary collisions and delays of exchanging drivers' details and investigating minor crashes by the side of a freeway can be eliminated by directing vehicles to pre-determined locations off the road as depicted in Figure 7.

Figure 7 – Directing vehicles off the I-90 freeway near Chicago

Photograph: Sonia Roberts

Conclusion

Police undertake activities ranging from responding to armed offenders to working on roads where risks can be elevated but where there is no option but to provide the service. At times, conflict can arise between the legislated responsibilities of the Police Act and the WHS legislation.

Operation Freeflow, the median strip working party and outcomes have shown that provided that controls are implemented, work health safety and road safety can be complementary and not mutually exclusive.

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New South Wales Level Crossing awareness and enforcement campaign: four years of working together

Sen Sgt Michael Timms, B Prof Stud Policing (UNE), NSW Police Force

Abstract

In 2012, conference was told of a new multi-agency campaign in NSW targeting level crossing safety. Up to that point, an average of one person each year had been killed in a collision between a road vehicle and a train in a state with 1,400 public road level crossings.

The Level Crossing Awareness and Enforcement Campaign combined the resources of the New South Wales Police Force and Transport for New South Wales to raise driver awareness of level crossing safety through a localised education and media strategy supported by the tasking and deployment of additional police resources to enforce road rules.

Now its fourth year, the campaign has delivered over 23 localised campaigns targeting some 48 level crossings throughout NSW and three years have passed since the last fatal crash at a level crossing.

The partnership has led to fresh collaborations such as educational displays at major regional events featuring *Pearly Gates*-messaging and a crashed car kindly donated by a driver involved in a level crossing crash.

Along the way, we have discovered level crossing safety is more than obeying the flashing lights or the signs.

This paper will outline the lessons learned about other adverse behaviours including driver distraction, speeding, the over-representation of heavy vehicles and local drivers in level crossing crashes.

The strategic use of social media will also be discussed as well as maintaining the on-going participation of law enforcement in enforcing level crossing safety long after the campaign has finished.

Introduction

The first paper on the Level Crossing Awareness and Enforcement Campaign (LXAEC) presented at the 2012 Australasian Road Safety Research Policing and Education Conference in Wellington NZ outlined the arrangements for the management of level crossings in NSW and how the LXAEC came to be.

The New South Wales Government's NSW2021 plan is "the NSW Government's strategic business plan, setting priorities for action and guiding resource allocation" (https://www.nsw.gov.au/sites/default/files/nsw_2021_plan.pdf). NSW2021 contains goals related to all areas of governmental administration including transport.

Within the area of roads and road safety, two goals are of particular significance:

Goal 7 Reduce Travel Times

Goal 10 Improve Road Safety

Up until 2012, NSW had averaged approximately one fatal crash level crossing involving a vehicle and train per year. By comparison, the annual road toll in 2012 was 369. The focus of police with regard to the road toll is therefore weighted towards behaviours such as speeding and alcohol, as well as proactively patrolling the freeways and state highways to reduce crashes and to quickly clear incidents that do occur.

Although crashes between vehicles and trains in New South Wales have been declining over the decades, the independent rail regulator, now known as the Office of the National Rail Safety Regulator (ONRSR) continues to receive “near miss” reports from train drivers, some of which are so close that the train drivers can see the vehicle registration numbers.

This presented an opportunity to develop a program that deploys education and enforcement to level crossings where adverse driving behaviour had been identified but does not come at the expense of other road safety taskings such as school zones.

Originally devised to target vehicles queuing over railway tracks, the LXAEC quickly earned a solid reputation within the Level Crossing Strategy Council (LCSC), the interagency group that oversees level crossings, as a cost effective means of increasing road safety issues around level crossings.

At the conclusion of the 2012 paper, it was indicated that the program for 2012-13 was to target motorist’s non-compliance of level crossing controls. Although queuing over railway tracks is inherently dangerous, the data from the regulator tabled at LCSC meetings indicated that disobeying stop signs, flashing lights and bells were the common factor associated with level crossing crashes.

Indeed both Kerang and the “five mates” crash at Gerogery near Albury in 2001 that led to the establishment of the LCSC involved driving contrary to level crossing controls.

Who is involved?

The LXAEC primarily involves New South Wales Police Force (NSWPF) and Transport for New South Wales (TfNSW). It is these agencies that devise and deliver each campaign with the assistance of the relevant local road and rail agencies that are consulted prior to the delivery of each individual campaign.

NSWPF and TfNSW have had continuity amongst the staff responsibly for planning and organising the LXAEC. A Level Crossing Communications Working Group (LCCWG) has also been formed as to advise the LCSC and TfNSW communications officers have delivered new educational materials and initiatives that have assisted the LXAEC.

For roads, the regional Roads and Maritime Services, (RMS) or the local council will be called upon to assist with local logistics and advice. For rail, NSW Trains or the Australian Rail Track Corporation (ARTC) is consulted prior. The attitude and support for the LXAEC has been positive with some councils making additional efforts to promote level crossing safety within their communities. The effectiveness of the campaign would be diminished without the involvement of the local road and rail authorities.

Traffic and Highway Patrol Command (THPC) provides the on-road enforcement of each campaign plus coordination and public awareness.

Funding for the LXAEC continues to be drawn from the Level Crossing Improvement Program which funds engineering upgrades to level crossings as well as education and research. The improvement program is overseen by the LCSC who endorse the annual

$80,000 budget for the LXAEC. Just over half of that funding goes towards the suite of public awareness measures with the remainder allocated towards the enforcement resources in the form of overtime for highway patrol members.

What is involved?

Around the start of each financial year, the small planning team meets to devise a campaign matrix for the following twelve months. The aim is to deliver four individual campaigns throughout the year. Within each campaign, two to three level crossings will be selected for the full suite of measures.

Site selection process

The planning group liaise with police, roads and rail agencies seeking nominations for sites to be targeted during the year. The process results in a campaign matrix to be delivered in the next twelve months.

Sites selected have been a mix of "active" and "passive sites". Active sites are defined as having flashing lights, bells and may also have boom gates. Passive sites are controlled by stop signs although there are a few sites in NSW with give way signs as the control. Sites selected have been predominantly in regional areas or in the Illawarra.

Data from the regulator relating to crashes at level crossings and near miss incidents is examined as it is a consistent source of information. This is because rail operators are required by legislation to report "notifiable occurrences" on the network to the regulator. The incident information records specifics such as collisions with boom gates, a short narrative and the date of occurrence so trends at particular sites can be noted.

Highway Patrol supervisors are asked to submit sites that may be suitable and these are compared against data from the regulator. Broken Hill in 2014-15 was case in point.

When a fatal crash occurs at a level crossing, it is the train driver who is the last person to see the deceased alive. Train drivers have a unique perspective on motorist's behaviour.

At the most recent campaign near Casino in northern NSW, two sites were originally to be targeted. However TfNSW received information from train drivers that a third site was of concern and it was included in the campaign.

In addition to crash and near miss data, the number of trains and vehicles per day that traverse short-listed sites are examined. Although the expenditure is modest compared to some programs, public monies are involved and all efforts made to ensure that campaigns occur in locations where maximum safety benefits can be realised.

Campaign planning

Once the campaign matrix is agreed upon it receives the endorsement of the LCSC. Planning for each individual phase starts two to three months out. Commitments are obtained for police resources and a teleconference is held between the full time planning group members and the relevant road and rail participants.

Roads and rail authorities are asked to nominate locations for the placement of portable variable message signs (VMS), advice regarding train running times, and whether road or track work is scheduled that may impact on the enforcement window, eg, no trains running.

There is flexibility within the planning process to adjust timings and trigger dates should the teleconference reveal that road or track works are to be held during the proposed campaign.

Train running times assist police in tasking with the view to having a highway patrol vehicle on site when a train is going through when any active controls (lights/bells/booms) are operating.

The catchment area for the letterbox drop is also determined during this phase. Residences near the level crossings selected will receive a pamphlet featuring the “pearly gates” message.

Figure 1: TfNSW “Pearly Gates” public awareness pamphlet

The reverse side of the pamphlet advises that that trains can take up to three football fields to stop and that police are now targeting level crossings in the area.

Public awareness phase

TfNSW issues a media release at the start of the public awareness phase. The release tells of the campaign as well as general information on level crossing safety. The letterbox drop occurs in the public awareness phase which usually lasts for two weeks. TfNSW also programs radio and local press advertising during this phase.

Variable Message Signs appear at the approaches to level crossings being targeted. Those signs advise drivers to “obey level crossing controls” with the penalty for non-compliance.

Giving as much warning that the campaign is taking place is of assistance in deflecting any criticism should motorists complain about receiving a penalty notice during the enforcement window.

Level crossings on heavy vehicle and over-dimension vehicle routes are given special mention in public messaging. This is in light of Kerang and findings by the regulator in 2011 that “heavy vehicles are over-represented in level crossing collisions” (ITSR media release 25 August 2011).

Enforcement Window

The enforcement window commences about two weeks after the start of the public awareness phase. Educational measures such as the VMS presence at level crossings continue for the duration of the campaign.

The Police Media Unit issues a release at the start of the enforcement window advising police will be enforcing the controls at the nominated level crossings. This release is issued to traditional media outlets and is accessible via the NSWPF website.

The release will also include the number of near misses at the sites in recent years however the term “near hit” is now being used to reflect the view of rail industry group TrackSAFE, that “near hit” better reflects the potential danger from such incidents (http://tracksafefoundation.com.au/rail-safety-week/).

NSWPF also utilises their extensive social media presence by uploading the level crossing release on twitter and Facebook. As of mid-June 2015, THPC had 169,000 followers of their Facebook page and the main NSWPF page had 480,000 followers. Some 90,000 people follow the NSWPF twitter feed. The number of people following NSWPF on social media now exceeds the number of people watching some nightly Sydney news broadcasts, or the number of people reading certain newspapers.

Figure 2: Highway Patrol vehicle during the Broken Hill campaign

Photo by Broken Hill Highway Patrol

Figure 2 depicts the highly visible approach that is taken whilst conducting campaigns. Although this can limit the number of offences detected, the campaign is about deterrence not detection. Due to the heightened level of public awareness, motorists caught during these campaigns can expect to receive a penalty notice ($425 as of 1/7/15 and three licence demerit points).

Level crossing controls are the primary offence targeted. Unlike a stop sign where a motorist can commit an offence at any time, controls at active sites needed to be triggered by an approaching train in order for disobey control offences to occur.

Over the course of the campaign, other behaviours that impact on level crossing safety have now been included as secondary offences during these campaigns.

A speed survey conducted by TfNSW prior to campaigns in the Hunter Valley in 2014 showed some that on some days, 10-20% of vehicles that traverse the surveyed level crossing were travelling in excess of the sign-posted speed limit of 100km/h. Those vehicles would have difficulty stopping if active controls such as flashing lights were to activate.

Driver distraction is an emerging road safety challenge and no more so than when motorists should be directing their attention to on-coming trains and level crossing warnings. Over the years, these campaigns have identified dozens of drivers committing mobile phone offences and highway patrol lookout for these offences.

Post Campaign

Following each campaign, the participating highway patrol section is debriefed and the details of any offences detected and items of interest are obtained. TfNSW also makes note of any difficulties and areas that could be improved upon next time.

A police report on the activities is prepared and tabled at the next LCSC and the LCCWG meetings. Where level crossing offences have been detected, the police report will include demographics of offending drivers and vehicle type with a view to ensuring that future awareness messaging are targeted to the groups most likely to be offending at level crossings.

Outcomes and Evaluation

Over the four years of the LXAEC, some 307 penalty notices have been issued to motorists for road rules offences at level crossings during campaign phases. Most of those offences have been for disobeying stop signs (Rule 121, Road Rules 2014).

Although the purpose of the highly visible police enforcement is deterrence rather than detection, the LXAEC appears to have raised the level of awareness and interest in level crossing road safety of police beyond the areas that have hosted campaigns. The number of state-wide penalty notices issued for level crossing offences has risen from a baseline of 263 in 2011 to 442 in 2014, an increase of 68% over three years. Sites targeted during the LXAEC contributed to about 20% of total penalty notices issued for these offences.

During 2014, police detected level crossing traffic offences at over 75 towns/localities throughout the state. Enforcement legal actions are not the only area where NSWPF has been more active with opportunities being seized with public awareness and social media engagement. Penalty notice data for 2011 to 2014 appears in Table 1.

Table 1: Legal Actions (penalty notice) Level Crossing Road Rules offences

Year	Legal Actions
2011	263
2012	271
2013	392
2014	442

Provisional Police Data

Dissecting level crossing offences detected during the LXAEC has shown that offending drivers are more likely to be local drivers or at least motorists from other rural areas. There is an absence of "novice" drivers offending and most offences have been committed by males over the age of 40.

The other sources of data that can be used to evaluate the LXAEC are near miss occurrences. Near miss data, a factor in site selection, have been examined pre, during and post-campaign to see if the LXAEC has made an impact in the occurrence of near misses between trains and vehicles at targeted locations.

Table 2: Near Miss data from targeted level crossings

Year	No. Of Sites targeted*	Near Misses Jan 2009 to May 2015	No. Of Near Misses before campaign	No. Of near misses during campaign	No. Of Near misses after campaign
2011(pilot)	2	0	0	0	0
2011-12	7	8	0	3	5
2012-12	8	59	46		7
2013-14	13	43	38		2
2014-15	3	14	13	1	0
Totals	**33**	**124**	**97**	**4**	**14**

Data compiled by TfNSW

*Not all locations measured due to site improvements such as grade separation

Table 2 indicates that of 124 recorded near misses at LXAEC-targeted level crossing, only 11% were recorded following a campaign.

As with most road safety campaigns, the benefits and improvements can diminish over time. In this case, most of the post-campaign near misses have occurred at sites visited in the early years. This data was examined during the planning process for 2015-16 to see if some sites need to be re-visited.

In early 2015, TfNSW engaged Deloitte Touche Tohmatsu (Deloitte) to prepare the business case and to undertake the evaluation of the Level Crossing Improvement Program including the LXAEC. That report found that the benefit to cost ratio of the LXAEC was 7.12.

Perhaps most importantly, more than three years have elapsed since the last level crossing fatal crash in March 2012. Whilst this result can be attributed to a combination of the E's of road safety, the LXAEC has been ongoing throughout the state during this time and should be credited accordingly.

New Opportunities and initiatives

Since the 2012 conference paper, several new initiatives have eventuated as a result of the LXAEC partnership.

Social media

Experience has shown that there is a public appetite for the strategic use of social media promoting level crossing safety. In late September 2014 a post on the TfNSW level crossing safety display at the Henty Field Days (attended by 60,000 people in Southern NSW) resulted in a reach on both the NSWPF main Facebook page and the Traffic and Highway Patrol Command page of 275,000 people.

By comparison, a post on fatigue and "driver reviver" sites over the October Labour Day long weekend on the THPC facebook site could only attract a reach of 15,464. Only 2% of people engaged with the fatigue post, compared to 18% of the level crossing item, and comments ran 29 to 1 in favour of the level crossing post.

Crashed car display

In June 2013, a level crossing crash occurred at a level crossing in southern NSW where a country motorist drove contrary to flashing lights and bells before colliding with the side of a freight train. The vehicle was then spun around before being dragged along for ten metres. Fortunately the driver who was the sole occupant was uninjured as the car was travelling at a low speed.

Police and TfNSW obtained the details of the driver as this presented a unique opportunity to "debrief" a driver who survived a level crossing crash. The driver had already been issued with a penalty notice so there was no impact on the crash investigation.

The driver explained that they had just driven off from an adjacent intersection and was "looking through" the level crossing at the junction with a highway on the other side of the railway tracks. This highlights that engineers need to be mindful of treatments when railway tracks run parallel to a main road. The driver had also come from visiting a patient in hospital and may not have been concentrating as much as they should have on their driving.

Figure's 3 and 4: 2013 Crash and 2014 Henty Field Days display

Photo's: Albury Highway Patrol (3) and TfNSW (4)

Efforts being made by TfNSW and NSWPF to improve safety at level crossings were explained to the driver.   As the vehicle was uninsured and beyond repair, the owner agreed to donate the vehicle so it could be used for level crossing public awareness in the hope that future tragedy can be averted. The driver did not want to be credited and asked that nothing be said that could identify them. Those wishes are being respected here.

Field days display

About the same time, moves were underway for TfNSW to stage the first level crossing display at the mid-September Henty Fields Days in southern NSW. The crashed car and TfNSW's "pearly gates" display are integral to the display. Henty Field days is now an annual event and along with displays at Orange and this year, Gunnedah Ag Quip, the message of level crossing safety has been taken to the communities most at risk from level crossing crashes.

Visitors to the field days site have an opportunity to express any concerns they have about level crossings. Measures are now being taken in NSW to remove "stop" signs at level crossings on disused lines. Members of the public visiting the Henty Field Days display raised concerns that the presence of these signs encouraged non-compliance which road users may then carry over onto active lines, with potentially fatal consequences.

Another issue which has been raised is the difficulty motorists have in seeing freight cars at night time at unlit passive level crossings. The cleanliness and on-going maintenance of any reflective marking on the side of coal cars has also been questioned by visitors to the field days.

Road or rail; whose problem is it?

Issues around level crossing design and compliance by motorists who have a legal responsibility to comply with controls raises a broader question as to who is best to improve safety at level crossings; road safety, the rail industry issue, or both?

Thus far, there has been a dearth of road safety participation at forums such as the recently formed National Level Crossing Safety Committee. The interface between road and rail and the trains that use level crossings could benefit from the safe systems framework as it is applied to road safety.

Conclusion

The LXAEC is an example of the conference theme of "taking action together". It is a model that could transfer to other road safety issues.

The campaign is borne from an engineering program to upgrade level crossings and uses a combination of education and enforcement to deliver improved safety for a modest cost. These benefits have been felt beyond the local areas that have hosted campaigns and the partnership between TfNSW and NSWPF has seized on new opportunities to further promote awareness and community input into road safety at level crossings.

Acknowledgements

The work of Godwin Camilleri and Nicole Douglas from Transport for NSW is acknowledged. Both have worked tirelessly to delivering the LXAEC and related initiatives such as the field days displays (in all weather conditions). Neither the Level Crossing Awareness and Enforcement Campaign nor this paper would have been possible without the assistance and support of the Godwin and Nicole.

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Towards Zero – Building a safe road system for Victoria

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Abstract

During an average week in Victoria, five people are killed and a further 100 people are hospitalised following road crashes. There are far too many deaths and injuries and the ripple effect of road trauma is enormous. The Transport Accident Commission (TAC) no longer accepts deaths and serious injuries as being inevitable consequences of having a road network. The TAC's vision is for a future where no one will be killed or seriously injured and where every journey is a safe journey.

In order to realise the vision, the TAC must bring to life and implement initiatives which are guided by the principles which underpin the *Towards Zero* approach. This paper will detail the TAC's strategy of initiatives being used to help Victoria move *Towards Zero*.

Introduction

The Transport Accident Commission (TAC) is a Victorian Government owned organisation, established under the *Transport Accident Act 1986* to reduce the social and financial cost of transport accident injuries to the Victorian community. Motorists in Victoria pay a transport accident charge as a part of their registration and this is used to fund the work of the TAC and pay for the treatment and support services for people injured in transport accidents, promote road safety and to improve the state's trauma system.

As the compulsory third party insurance agency for personal injuries, the TAC has a natural financial interest in ensuring as few people as possible are injured and killed in transport accidents. In the 2013-14 financial year, the TAC paid out in excess of $1billion for support services and benefits to over 47,000 people (TAC, 2014). The TAC pays an average of $150,000 for each road death and an average of $1,500,000 for each serious injury such as traumatic brain or spinal injuries (TAC, 2015). Reducing the frequency and severity of transport accidents not only saves lives and avoids serious injuries, it also reduces the number of claims the TAC receives. This provides a saving to the Victorian community and also ensures the long term financial viability of the transport accident scheme.

However, the TAC's motivation to prevent deaths and injuries also extends well beyond any financial savings prevention initiatives may deliver. The TAC understands that road trauma can be life changing and recovery a long journey. This is what James, a TAC client, had to say about his journey to recovery:

'I was in rehab for almost a year. I had to relearn how to do everything again, including eating and walking. It was hard, especially the co-ordination. I felt like a newborn. Now I can walk up stairs and easily go for a walk. I feel very good and have a great sense of achievement' – TAC, 2014

The TAC sees first-hand through the clients it cares for, the impact road trauma can have on the lives of the people affected as well as their family and friends and this serves as one of the biggest motivation to prevent similar tragedies from occurring again.

Deaths and serious injuries do not have to be the inevitable consequences of having a road network. However, right now, during an average week in Victoria, five people are killed and a further 100 people are hospitalised following road crashes and the ripple effect is enormous. This is too big a price to pay to have a road system and the TAC does not accept that death and serious injury is an inevitable consequence of having an effective road network. The TAC's vision is 'where every journey is a safe journey', for a future where no one will be killed or seriously injured when using the road. It aims to fulfil this vision through its internal accident prevention strategy and through its role within the Victorian Road Safety Partnership (consisting of the TAC, VicRoads, Victoria Police, Department of Justice & Regulation and Department of Health & Human Services).

The need for action

Victoria has a proud road safety history, leading the world on a number of fronts through road safety initiatives, including being the first jurisdiction to introduce:

- mandatory seatbelt wearing in 1970
- random breath testing in 1976
- random drug testing in 2000

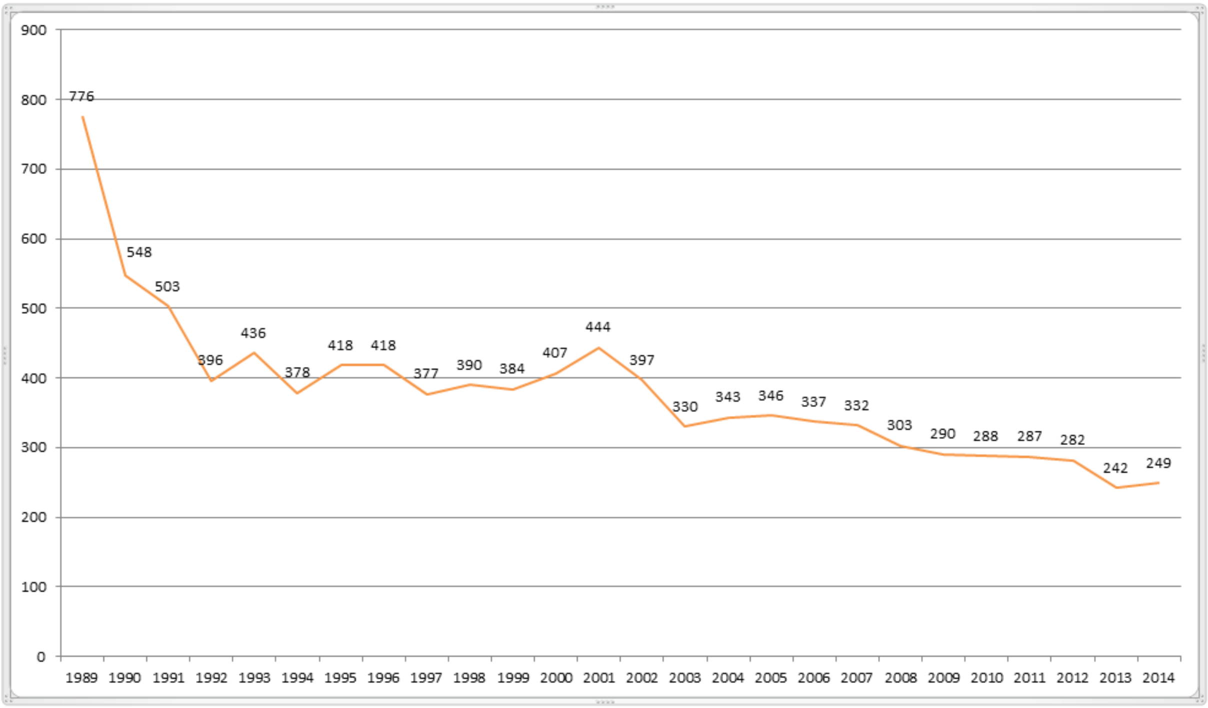

Fig 1. Number of road deaths in Victoria between 1989 and 2014

Despite achieving record low road death results year on year between 2005 and 2013 (refer to Figure 1), Victoria has fallen well behind on the world platform. In 2003, Victoria ranked 5th with 6.7 deaths per 100,000 population, when compared to 24 other OECD nations (Bureau of Infrastructure, Transport and Regional Economics, 2005). However, by 2012, Victoria has slipped to 16th place, with 5.01 deaths per 100,000 population (Bureau of Infrastructure, Transport and Regional Economics, 2014).

The current Victorian Road Safety Strategy aims to achieve a 30% reduction in fatalities and serious injuries between 2013 and 2022. If Victoria was to reach its target reduction for fatalities by 2022, this would equate to 3 deaths per 100,000 and still place Victoria more than a decade behind some of the best performing jurisdictions in the world. These countries include:

- United Kingdom - 2.8 in 2012
- Norway - 2.9 in 2012
- Sweden - 3.0 in 2012
- Denmark - 3.0 in 2012 (Bureau of Infrastructure, Transport and Regional Economics, 2014)

It is clear additional actions needs to be taken to help Victoria further reduce road trauma. The fact that other countries can achieve such positive results encourages the TAC to better understand and learn from the experience of some of the world's best performers in road safety. In particular, the building of a safer road system with respect to the *Vision Zero* and *Sustainable Safety* principles of Sweden and The Netherlands respectively, and developing a greater safety culture as seen in many of these jurisdictions are areas in which the TAC can play an important role in moving Victoria *Towards Zero.*

What needs to be done?

Implementation of Towards Zero

Towards Zero has been successfully implemented in a number of countries, including in Sweden and The Netherlands. Since 1997, when Sweden implemented *Towards Zero* (otherwise known as *Vision Zero* in Sweden), the number of road fatalities have more than halved, from 541 in 1997 (Lie & Tingvall, 2009) to 260 in 2013(Swedish Transport Administration, 2014).

At the heart of Towards Zero is the belief that life and health are paramount to all else and should be the first and foremost consideration when designing a road network. The principles underpinning Towards Zero acknowledge that:

- As people, we will inevitably makes mistakes at some point; however, no one should die or be seriously injured on the road as a result of these mistakes.
- The human body is only built to withstand forces up to the equivalent of 30km/h, after which the risk of dying increases significantly.
- Understanding that people are fallible and fragile, we need to build a forgiving system that can absorb our mistakes and limit the transfer of forces that can result in serious injuries or death.
- Road safety is a shared responsibility between everyone in the community.

To help build a safe road system forgiving of our mistakes, we need to invest heavily in the creation of:

- Safe Roads
- Safe Vehicles
- Safe Speeds and
- Safe Road Users

Towards Zero challenges the traditional understanding of how to address road trauma, looking at how the elements that our road transport system is comprised of can work together to protect people from being killed or seriously injured. The key differences between the traditional and *Towards Zero* approaches have recently been summarised by the Swedish Transport Administration in Figure 2 below.

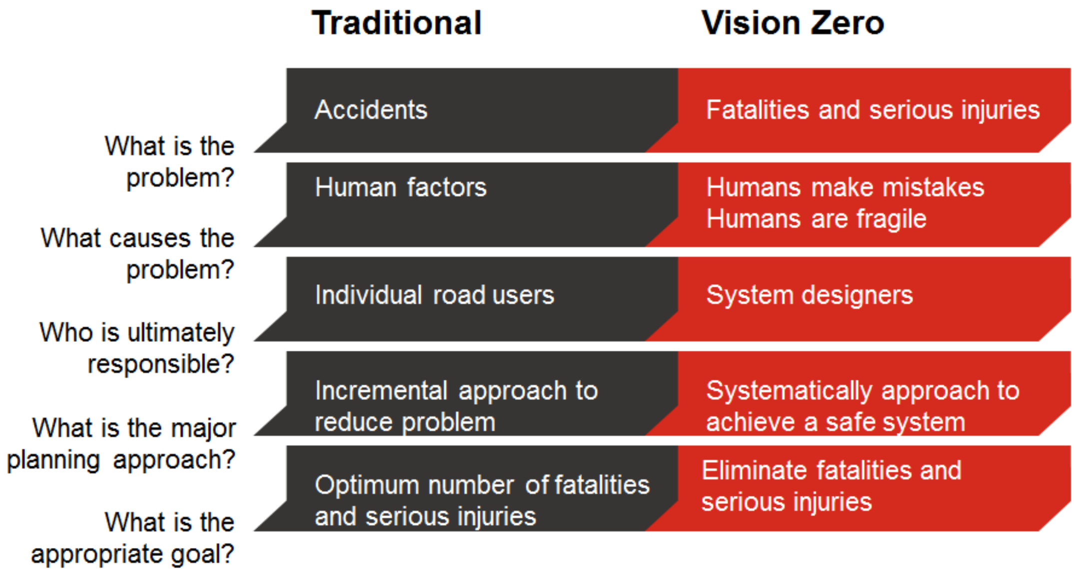

Fig. 2. – Traditional Approach to Road Safety compared with the Towards Zero/Vision Zero approach

(Source: Swedish Transport Administration, 2015)

The TAC adopted the key *Towards Zero* principles as the underpinning philosophy for its internal road safety strategy some years ago, and more recently, other partner agencies and the Victorian Government has adopted these principles for the state. Interestingly, the TAC scheme was formed in line with the principle of people making mistakes. The TAC is a no-fault insurance scheme, formed on a legislation that assumed all people leave on any journey with the same expectation – that they will arrive at their destination safely. If people do not arrive safely and are injured, they are then entitled to the same level of medical and care no matter what the accident circumstances, The scheme is not concerned with who is at fault in an accident. Medical benefits will be paid to an injured person regardless of who caused the accident. The *Towards Zero* approach is a good fit for the TAC. Moving forward, the *Towards Zero* principles will be systematically applied to all future TAC road safety initiatives.

Development of a Safety Culture

The culture of a society can help shape the attitudes and behaviours of the community. It is therefore vital for road safety agencies to encourage the development of a culture in which safety is the primary consideration when designing and using the road network. When a person is killed or seriously injured on the road, it indicates the current road system needs to be strengthened to prevent a similar tragedy from occurring.

Under *Towards Zero*, the safety of the road system is primarily the shared responsibility of the system designers and the users of the system. In the past, it was assumed that safety could be improved by just working on road user behavior, leading to a 'blame the victim' approach where road users are made to bear the majority of the responsibility in the event of a crash. *Towards Zero* sees the focus shift from 'blaming the road user' for mistakes they may make, to understanding the deficiencies in the road system as a whole and examining how the system can be improved to prevent future accidents. Creating a greater safety culture will rely on educating key designers of the system and the community about the elements of the road system and how good design can work together to keep everyone safe. The aim is to create a culture where safety is the norm and not the exception.

The current road system and culture is a product of the traditional thinking and approach to road safety. To fully embrace *Towards Zero,* the thinking on the issues faced and how to address them must also change. This will involve a true culture change as key designers of the road system as well as the community will be challenged to think differently about life and death and how the road network is used. The building of a safe road system for Victoria and the development of a safety culture is a long term plan and will not be achieved overnight, but for a future where zero deaths and serious injuries is a reality, step actions must be taken now and in this regard, the TAC can play an important role.

TAC's Strategic Approach to *Towards Zero*

Under the *Transport Accident Act 1986,* the TAC has a responsibility to reduce the incidence of transport accidents and to reduce the cost to the Victorian community of compensation for transport accidents. As a lead agency within the road safety partnership and a key designer/influencer of the system, the TAC also has a big role to play in ensuring a safe road system is in place to prevent the occurrence of deaths and serious injuries.

The TAC has a long history of investing in initiatives that meet both the objectives of saving lives and reducing costs to the community. One example is the promotion of curtain airbags to increase consumer demand for the technology. Research has shown that curtain airbags can reduce driver deaths in the event of a side impact by up to 40% (Insurance Institute of Highway Safety, 2006) and the probability of head injuries among occupants of a car equipped with a head protecting side airbag is 71.4% lower (Fiztharris & Stephan, 2012). With the TAC paying an average of $1,500,000 for each serious injury such as traumatic brain injuries (TAC, 2015), curtains airbags represented an important initiative and investment to help save lives, prevent injuries and reduce the TAC's claims costs, and thus the TAC has been actively promoting the safety benefits and availability of the technology to consumers (Truong, Cockfield, Thompson, Gubana & Mulholland, 2010).

The TAC recognises that to help build a safe road system in Victoria, it will need to continue to systematically invest in and implement initiatives guided by the *Towards Zero* principles in each of the key areas of safe roads, safe vehicles safe speeds and safe people, as well as invest in enablers such as capacity building, community engagement, communications and research.

Safe Roads

The key financial investment the TAC makes to improve road safety is road infrastructure. Roads and road features play a vital role in reducing crashes and/or the injury outcomes in the event of a crash. Improved infrastructure provides solid and well understood crash and injury reduction outcomes and are critical for long term and sustainable trauma reduction. The two key infrastructure programs the TAC invests in include:

Safe System Road Infrastructure Program

The TAC has committed $1 billion for the Safe System Road Infrastructure Program (SRRIP) to improve the road network in Victoria. The SSRIP has phased out the conventional blackspot approach to improved road infrastructure and moved to being guided by *Towards Zero* design principles.

The SSRIP funding goes towards programs such as:

- targeted high volume ‘M’ roads that have high-crash numbers
- intersection treatments such as installation of roundabouts and speed platforms
- run-off road treatments such as wider shoulders and medians, tactile edge-lines and wire rope barriers.
- Innovative trial programs to continually improve treatments types and costs.

Local Government Area (LGA) Grants Program

The LGA Grants Program is an opportunity for local government to apply for funding for small-scale infrastructure treatments to address pedestrian and cyclist safety. Local governments can apply for grants of up to $25,000 for planning and researching innovative safety treatments. Councils with plans already in place are also eligible to apply for matched-funding grants of up to $100,000 to cover the cost of implementing the new infrastructure.

Safe Speeds

The Safe Speeds component of *Towards Zero* is concerned with appropriate speed limit setting and compliance. If speed limits are not set appropriately (eg. guided by knowledge of the human body’s tolerance to external forces) and/or speed limits are not complied with, this can in turn affect the effectiveness of initiatives implemented in the road or vehicle space and contribute to road trauma.

To support the work undertaken under Safe Speeds, the TAC will:

- Produce public education campaigns to encourage speed compliance
- Provide support for local government to review their speed limits and adjust if they are not safe
- Support additional enforcement activity

In accordance with *Towards Zero* and with the aim of developing a safety culture, the TAC will provide information and assistance to help drivers and riders comply with speed limits and stay safe on the roads. In this regard, the TAC will continue to investigate and promote the use of technologies such as Intelligent Speed Assist (ISA), which provides a warning to drivers when they exceed the speed limit, as an assistant with compliance.

Safe Vehicles

Vehicles that are designed well and are safe can either prevent a crash from happening or reduce or absorb some of the forces, so that what ends up being absorbed by the body will be less than the equivalent of an impact at 30km/h – beyond which the risk of death significantly increases. The TAC recognises the potential of improving crashworthiness and the preventive capacity of vehicles in reducing road trauma, as research indicates that if every vehicle could be upgraded to the safest in its class, serious trauma could be reduced by a third (Newstead, Delaney, Watson & Cameron, 2004). Vehicles, along with roads, are the most permanent and sustainable road safety interventions. Once a vehicle is designed safely and have the appropriate safety technologies, the safety benefits should remain in place for the life of the vehicle.

To support the acceleration and adoption of Safe Vehicles in Victoria, the TAC will:

- Increase consumer awareness and demand for technologies that have proven road safety benefits - some examples of technologies the TAC has promoted include electronic stability control, curtain airbags (Truong, Cockfield, Thompson, Gubana & Mulholland, 2010) and auto emergency braking.
- Develop, demonstrate and promote new and emerging technologies with road safety potential via the TAC's SafeCar project (Truong & Cockfield, 2013).
- Support the dissemination and provision of independent vehicle safety information, such as Australasian New Car Assessment Program (ANCAP) and Used Car Safety Ratings program results, to assist the community make safe choices when purchasing a vehicle.
- Work with fleets to encourage the purchase of safe vehicles.
- Work with and encourage vehicles manufacturers and importers to make available technologies that have a proven road safety benefit.

Safe People

Towards Zero acknowledges that road safety is a shared responsibility and everyone in the community can play an important role. To support the community to help themselves and others stay safe on the road, the TAC will:

- Be transparent and share what we know about road safety to help them make the decisions about safety on the roads.

- Support Police enforcement to deter behaviours that could lead to road trauma.
- Engage with workplaces to encourage the adoption of a Safe Driving Policy for employees.
- Encourage the involvement of the community in making the road system safer, through initiatives such as the TAC's Community Road Safety Grant Program which offers community groups the opportunity to apply for funding for road safety projects.

Building Capacity

To build a safe road system, the key designers of the system must be well versed in the *Towards Zero* principles and understand the practical applications of the principles. Some of the key designers of the system include road engineers, road safety agency staff and local government. In order to build capacity, the TAC:

- has starting working with key road safety partners to develop and deliver *Towards Zero* training specific to their organisation to enable their staff to understand the *Towards Zero* principles, how to apply it to their work in designing the system and their role within the system.
- developed an e-learning module to educate its own internal staff about *Towards Zero* and increase knowledge (Waller & Cockfield, 2014).
- will investigate and implement training for other key designers of the system such as local government staff.

Community Engagement & Public Education

Road safety is a shared responsibility and the road safety agencies need the assistance and support of the community. In 2014, the TAC and its road safety partners launched the inaugural Towards Zero Road Safety Leadership Symposium which called on the leaders of Victoria to commit to assisting Victoria move towards zero deaths and serious injuries. At the event, leaders from different sectors learnt about *Towards Zero* and how they can assist. The Symposium will be an annual opportunity for the agencies to share with leaders how Victoria is performing in road safety terms and work together to do better. In addition, the TAC will continue to investigate other avenues to engage different sectors of the community in road safety.

The TAC recognises that if the community is to engage and join in the journey *Towards Zero* they need to be fully informed about the plan. Moving forward, the TAC's aim will be for more transparent communications that share with the community any knowledge about issues such as the human body's tolerance to energy forces, how wire rope barrier works to protect people, why certain vehicle safety technologies are so important, in order to increase their level of understanding and buy in to the vision and help foster the development of a safety culture of shared responsibility. Previous communications concentrated efforts on advising road users about how they should behave, however, new communications will be about sharing the data and evidence base and providing the information that will help the community make the best decisions for themselves.

To this end, the TAC is currently developing a series of communications designed to help the community understand the key *Towards Zero* principles of mistakes and human vulnerability, as well as how safe roads, safe cars, safe speeds and safe people interact to reduce road trauma. This series of campaigns will be the launch of the TAC's new *Towards Zero* communication approach.

Research

To help build a safe road system for Victoria, all initiatives implemented must be guided by sound research evidence demonstrating an impact in reducing deaths and serious injuries. One of the most significant research investments for the TAC currently is the Enhanced Crash Investigation Study (ECIS). ECIS is an $8 million research program designed to examine more than 400 serious injury crashes in detail to provide an understanding of how crashes and injuries occur. The outcomes from ECIS will help guide the TAC and other road safety partners' efforts in reducing accidents and the cost of serious injuries.

As Victorian continues work on building a safe road system, the TAC will continue to invest in further research as needed to help guide future investments and initiatives.

Conclusion

The ultimate road safety goal for Victoria is to have zero road deaths and serious injuries. In order to realise this goal, the TAC along with its road safety partners in Victoria, must bring to life and implement initiatives which are guided by the principles which underpin the *Towards Zero* approach. The TAC will continue to support the development of a safe road system in Victoria through its investments and initiatives and believe that with a systematic approach to road safety underpinned by *Towards Zero* principles, the vision of zero will be realised.

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Towards Zero & Safety Culture Communications – A new way of engaging with the community

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Abstract

As Victoria moves to implement the *Towards Zero* approach and adopt a safety culture, the nature of the Transport Accident Commission's (TAC) communications will also evolve. While the *Towards Zero* approach is a well-known philosophy amongst the road safety professionals, this is not well understood by the community. One of the key principles that underpin *Towards Zero* is a shared responsibility for road safety – of which the community needs to be an important part. To bring the community along on the journey *Towards Zero*, it is vital that they are privy to the same information as key designers of the system and are educated about the vision, its principles and key components.

Following substantial research and thinking, a new, long term, *Towards Zero* public education campaign is under development. The campaign aims to cement the long term goal of achieving zero road deaths and of providing information about how safe roads, safe cars, safe speeds and safe people interact to reduce road trauma. The Victorian community will, for the first time, be presented with a system's approach to trauma reduction.

This paper will detail the communication strategy and the first of the new *Towards Zero* public education campaign being used to engage the community as Victoria journeys *Towards Zero*.

Introduction

The Transport Accident Commission (TAC) is a Victorian Government owned organisation. Motorists in Victoria pay a transport accident charge as a part of their registration and this is used to fund the work of the TAC and pay for treatment and support services for people injured in transport accidents. In addition, the TAC works closely with its road safety partners (consisting of VicRoads, Victoria Police, Department of Justice & Regulation and Department of Health & Human Services) to reduce the incidence of road trauma through accident prevention programs, including public education campaigns.

One of the main responsibilities of the TAC within the road safety partnership in Victoria is the promotion of road safety. The TAC has a long history of producing innovative public education campaigns which educate the community about road safety behaviours. As Victoria moves to implement the *Towards Zero* approach and adopt a safety culture, the nature of the TAC's communications will also evolve.

Towards Zero

At the heart of *Towards Zero* (otherwise known as Vision Zero, Sustainable Safety or the Safe System approach) is the belief that human health is paramount and that no one should die or be seriously injured when they use the road. The key principles that underpin *Towards Zero* are:

- As humans, we will all inevitably make mistakes
- As humans, we are vulnerable - our unprotected bodies can only withstand forces equivalent to an impact speed of 30km/h before the risk of death significantly increases
- Road safety is a shared responsibility between everyone in the community.

Understanding these principles, it is therefore important to build a safe road system that can accommodate people's mistakes and vulnerability and this will involve significant developments in:

- Safe roads
- Safe vehicles
- Safe speeds
- Safe people.

The *Towards Zero* approach is a well-known philosophy amongst road safety professionals, however, it is not a familiar concept within the Victorian community (Social Research Centre, 2013b). A key principle underpinning *Towards Zero* is a shared responsibility for road safety – for 'shared responsibility' to become reality, the community needs to understand and want to be involved in this new approach.

History of the TAC's Public Education

On 10 December, 1989, the first TAC television commercial (TVC) went to air. In the 27 years since, the TAC has produced in excess of 150 TVCs that have focussed on behaviours and issues which impact road safety significantly including speeding, drink driving, drug driving, distractions, drowsiness and fatigue, young drivers, parental role modelling, vehicle safety and technologies, motorcycle safety and police enforcement.

Traditionally, TAC campaigns have focussed on key road user behaviours and the role of the driver/rider and what individuals can do to reduce their risks on the roads. The campaigns have been successful in raising awareness of important issues such as drink driving and speeding and taglines such as 'If you drink then drive, you're a bloody idiot' and 'Wipe off 5' are well known and understood by the community. As Victoria moves to implement *Towards Zero*, it is opportune for the TAC to consider and evolve its communication approach and the first step is to consider where the community is at with road safety.

Where is the community at with road safety?

The TAC regularly conducts surveys and focus group research to monitor the community's attitudes and self-reported behaviour in relation to a number of road safety issues in order to better tailor communication campaigns suited to where the community is at.

Through the initiatives undertaken in road safety and in conjunction with the TAC's public education campaigns, the community is currently well aware of the key behaviours that contribute to increased road trauma risk (refer to Figure 1) and find many of them socially acceptable (refer to Figure 2).

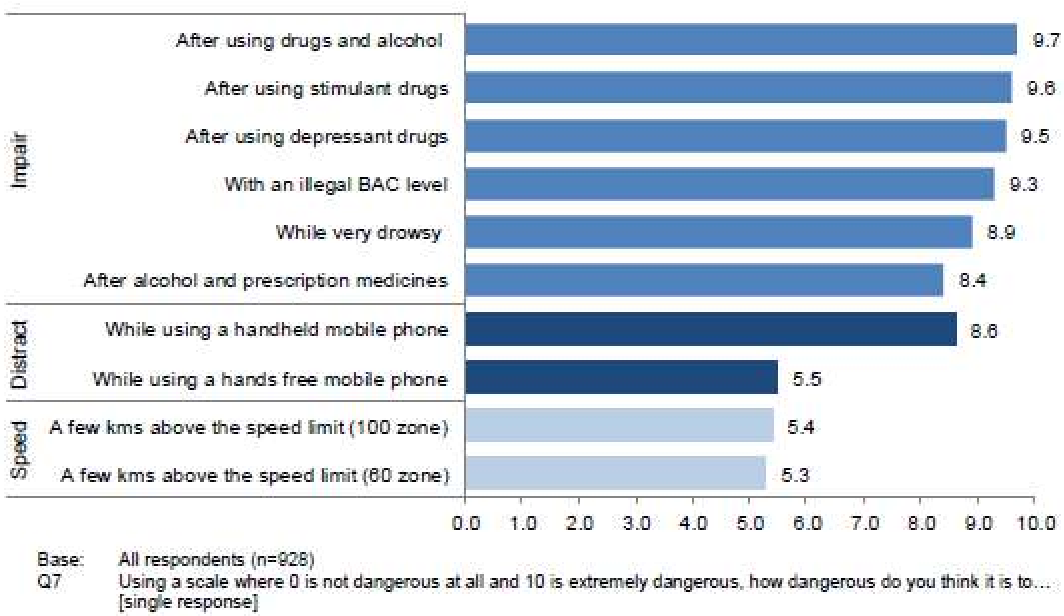

Fig. 1 – Community perception of level of danger in driving behaviours

(Social Research Centre, 2013a)

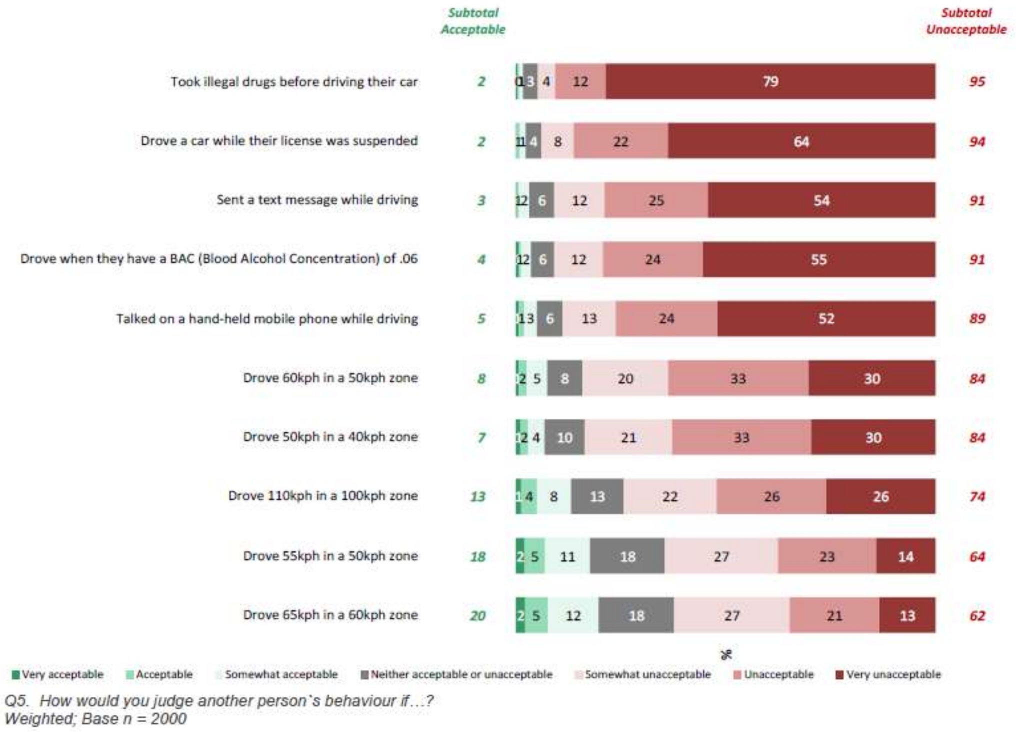

Fig. 2 – Social unacceptability of driving behaviours (Ipsos, 2014)

What the community is not as well aware of is the *Towards Zero* philosophy. When asked in research whether they have heard about the Safe System (i.e. *Towards Zero)* approach to road safety, only 11% of respondents indicated that they have (Ipsos, 2014). This is perhaps not surprising. Even though *Towards Zero* is the underlying philosophy that has been embraced by road safety professionals and is referred to in many policy documents, there has not been a systematic approach to educating the community about the concept.

The aim of *Towards Zero* is to have zero deaths and serious injuries on the road. Currently, research shows that a large majority of the community (78%) think that the idea of no road deaths is unachievable, with some of the barriers being:

- Human error (68%) and people will always make mistakes (20%)
- Driver stupidity (14%)
- Driving under the influence of drugs or alcohol (11%)
- Technology would never be fully safe (10%) (Ipsos, 2014).

However, when *Towards Zero*/Safe System was explained as an approach in which nobody needs to be killed or severely injured on Victoria's roads based on safer road users on safer roads, with safer speed limits and in safer vehicles, 38% of respondents believed that *Towards Zero/*Safe System is achievable (Social Research Centre, 2013b). It can be argued that the community would require some context and information on how road trauma can be reduced in order to believe that zero deaths is ever achievable.

The community may also require some convincing that road safety is an issue that concerns everyone, including themselves personally. With 25% of the community believing that the barrier to achieving zero is due to driver stupidity or deliberate risk taking (Ipsos, 2014), they may think that they are immune to the effects of road trauma if they do not engage in those behaviours. Past campaigns have focussed on poor driver behaviour, but the fact that accidents can happen even when not deliberately taking risks (eg. making a mistake) is not highlighted. With 81% of people rating themselves as better than average or much better than average drivers (Social Research Centre, 2014), the key principle of everyone makes mistakes need to be clearly communicated to convince road users that road trauma can happen to anyone that makes a mistake, including those that believe they are good drivers and hence the need build a road system to accommodate for instances where people do make mistakes to prevent death and serious injuries.

In relation to who is responsible for reducing road trauma, focus group research indicate that more work needs to be undertaken to foster a sense of ownership of the problem in the community. For example:

People feel that this (road safety rules) have been imposed upon them, they need to feel they have ownership of it…Like I said, we need to feel ownership of this thing. We don't. I don't, I don't feel it apart from playing my own little business on the road I don't have any ownership or part to play in what those statistics are showing. (55+ years Melbourne) – (Kerryn Alexander Research, 2014).

The community has also indicated that they would like more information that provides the rationale for why certain strategies are implemented or actions are taken. One example is speed limit setting. In focus group research there appeared to be a greater acceptance of changes to speed limits, once the link between human tolerance and impact speeds was explained:

That gets back to the point that it needs to be communicated. Everybody needs to be aware of the numbers and what everybody is trying to do to prevent it. There is not a lot out there about it. I didn't know a pedestrian could get killed at 30 k's. (Female, 20-30 years, Bendigo) - (Kerryn Alexander Research, 2014).

I think explaining the reason would be part of it. I think you're right if people don't understand the reason they're not going to change their behaviour. If they understand this is going to save lives and statistically based say it saves lives I think it will have more of an impact. (Melbourne CBD) - (Kerryn Alexander Research, 2014).

With Victoria moving to implement *Towards Zero,* road safety agencies will need to consider where the community is at with road safety and how to engage them to the embrace the vision, their role within the system and foster a sense of shared responsibility. Public education is one key avenue and to this end, the TAC has taken into account the research and has developed a new communications approach to bring the community on the *Towards Zero* journey.

A New Communications Approach

Public Education

One of the key principles that underpin *Towards Zero* is a shared responsibility for road safety – of which the community needs to be an important part. If it is believed that the community is a key part of the road system, it will be important for community members to be privy to the same information as available to the designers and builders of the road system in order for them to understand why changes are being made and what government are working towards. Road safety agencies and the government cannot realise the *Towards Zero* vision without all parts of the system doing their part - and this means gaining the support of the community.

Historically, the TAC's public education campaigns and communication have focussed on the behaviours and responsibilities of individual road users, of which they are now well aware of. They have rarely engaged or informed road users about the State's overarching road safety strategy and or longer term vision. It is argued that this lack of context and subsequent rationale for the communications, for some can act as a barrier to behaviour change.

If the community is to engage and join in the journey *Towards Zero* they need to be fully informed. Moving forward, the TAC's aim will be for more transparent communications that share with the community any knowledge about issues such as the human body's tolerance to energy forces, how wire rope barrier works to protect people, why ABS on road bikes is so important to motorcyclists' safety, in order to increase their level of understanding and buy in to the vision. Previous communications concentrated efforts on advising road users about how they should behave. New communications will be about sharing the data and evidence base the road safety partners use to inform Victoria's Road Safety Strategy and the resulting actions and providing the information that will help the community make the best decisions for themselves.

Safety Culture & Communications

The new TAC approach will aim to develop a safety culture in Victoria where it is acknowledged that the majority of people on the road behave in a safe manner. Under *Towards Zero*, road safety is a shared responsibility rather than the traditional 'blame the victim' approach where road users are assumed to be at fault or made to bear the majority of the responsibility in the event of a crash. Media reports will often note that alcohol, drugs or speed were thought to be involved but how often are issues such as the lack of barriers or a 2 star car was a major reason for a crash reported? In future, public education and media communications will tonally be quite different, with more emphasis on positive outcomes and on a range of issues that show that all parts of the road system have a part to play.

For example, instead of reporting the number of people Police caught transgressing in an operation, the report can instead focus on the number of people that behaved safely. This will normalize the positive behaviors in the community, rather than highlight the transgressions of a few and this will help develop a culture where safety is the norm rather than the exception.

Another example is when key spokes people are interviewed about a crash. Instead of speculating what road user behavior (such as speeding, drink driving, mobile phone use etc.) could be a causal factor, they can also comment on how the safety of the vehicle or the road could have played a part in either contributing to the death or injury or how if the driver was in a safer car or if there were barriers on the sides of the road, the tragedy could have prevented.

The first of the TAC's *Towards Zero* public education campaigns signals the change to this new approach in engaging with the community.

Towards Zero Public Education Campaign

The launch of *Towards Zero* will be a phased campaign designed to introduce the community to the key *Towards Zero* principles of mistakes and human vulnerability, and to understand how safe roads, safe cars, safe speeds and safe people interact to reduce road trauma. This campaign is about providing key information and encouraging the community to go to the *Towards Zero* website to find out more detailed information.

Naming the vision

The vision of achieving zero deaths and serious injuries is referred to around the world by a number of different names such as Vision Zero (Sweden), Sustainable Safety (The Netherlands) and the Safe System approach (Australia). In deciding on a name that would best engage the community, research indicated that *Towards Zero* would best serve this purpose (Kerryn Alexander Research, 2014). Generally, the community does not consider zero road trauma to be achievable. 'Towards Zero' was embraced in research because it conveyed an achievable goal, and more importantly was not immediately rejected. For example:

Towards Zero, I think it acknowledges it's a journey and it's not a tomorrow thing but we're on the path. (Melbourne CBD) - (Kerryn Alexander Research, 2014).

Phase 1 – The Ethical Approach

At the heart of *Towards Zero* is the belief that no one should be killed or seriously injured when using the road system. In focus group research, most participants agreed with this principle but, road trauma does not appear a top of mind issue for most people and the community's awareness of how many people are killed each year was low. There was also a consistent view that Victoria's reduction in the number of road deaths is a good achievement and if we can halve that number again or continually improve, that would be an acceptable goal (Kerryn Alexander Research, 2014). Only a small number of people indicated zero should or could be the goal.

Therefore, the aim of the first phase of the *Towards Zero* campaign is to put the ethical principle of no one should be killed on the road on the community's agenda. Phase one communication will personalise the issue of road trauma and help the community to understand and agree why zero is the only acceptable goal to aim for. The concept is centred around the idea that no one wants their family to be killed on the roads. We want the community to recognise that everyone that is killed is someone's family and there is no one someone won't miss, if they are gone. Therefore the only acceptable road trauma goal is zero.

Phase 2(a) - Why we need to build a safe road system and how do we do it?

People are fallible. Everyone will make a mistake at some point, whether it is on or off the road and whether they are aware of it or not. However, people should not die or become seriously injured on the roads because they made a mistake. There are over 4 million drivers on Victoria's roads – to expect every driver to not make a single mistake every time they drive is unrealistic.

However, currently, zero road deaths is not considered achievable by the community, with the key reasons being that human error is inevitable and that accidents are unavoidable (Kerryn Alexander Research, 2014; Ipsos, 2014). As mistakes is a key barrier, the campaign needs to acknowledge that people will always mistakes, and that a part of *Towards Zero* is about building a system that can accommodate people's mistakes, which if done successfully, will ultimately help us get to zero.

As the logical question that could be raised following Phase 1 communications is how zero road deaths can be achieved, Phase 2(a) aims to:

- share with the community what a safe road system can look like
- help the community understand that people will inevitably make mistakes when driving
- help the community understand how through building a safe road system, we can protect people when mistakes do occur.

The central idea for Phase 2(a) is 'Then and Now'. In 1970, Victoria recorded its highest number of road deaths. However, 40 plus years on, despite the growth in population and vehicles, Victoria has now managed to reduce the number of road deaths to approximately 250 a year. By looking back at historical trends and what has been achieved, the aim is to demonstrate to the community that Victoria can continue to do better, until the goal of zero is reached and the way forward is to build a safe road system involving safe roads, safe vehicles, safe speed and safe people, which can accommodate people's mistakes.

Phase 2(b) – Human Vulnerability

Humans are inherently vulnerable. There is only so much force bodies can withstand before they start to break, with death and serious injuries as a certain outcome. The unprotected human body can only withstand external forces up to the equivalent of 30km/h before the risk of death significantly increases. Focus group results indicate that community awareness of human vulnerability at different impact speeds and scenarios vary widely (Kerryn Alexander Research, 2014; Luma, 2015; Kerryn Alexander Research, 2015)

Humans are the centrepiece of *Towards Zero* and every action taken under the areas of safe vehicles, safe speeds, safe people and safe roads is about protecting the vulnerable human and the mistakes they make. Most initiatives to be implemented under *Towards Zero* will be based on the human vulnerability and tolerance principle. The community, therefore, needs to know about and understand this principle in order for them to appreciate and accept why certain measures need to be put in place to help further reduce deaths and serious injuries.

Phase 2(b) will be communication about human vulnerability and aims to increase awareness and understanding of how the human body can only withstand external forces up to the equivalent of 30km/h before the risk of death significantly increases. This piece of communication will then complete the picture of why we need to build a safe road system.

Sponsorship and PR

A key avenue through which the TAC engages with the community about road safety issues is via the use of sponsorships with sporting clubs and a range of other community partners. For example, Melbourne Victory Football Club and the TAC have been in partnership since 2005 and the club has assisted the TAC in promoting a range of road safety messages. Melbourne Victory has been an early adopter of the *Towards Zero* messaging – starting to promote it in their 2014-2015 season. A recent survey of Melbourne Victory supporters revealed a high awareness rate of *Towards Zero* and zero deaths and serious injuries messages (EY Sweeney, 2015), indicating sponsorship is one avenue to raising awareness of *Towards Zero.*

As TAC moves to further implement *Towards Zero* projects and engage with the community on the *Towards Zero* messages, sponsorship and supporting PR activities will play a vital role and the tone and method will be consistent with the TAC's new communication approach.

Conclusion

The *Towards Zero* campaign signals a change in approach to the TAC's communication and engagement with the community. The Victorian community will, for the first time, be presented with a systems approach to trauma reduction and be privy to information that helps guide and shape Victoria's wider approach to road safety. As road safety is a shared responsibility between everyone in the community, the new *Towards Zero* campaign will be the first step to sharing and engaging the community in the vision of zero road deaths and serious injuries and for them to join us in the journey *Towards Zero*.

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An analysis of driver behaviour through rural curves: Exploratory results on driver speed

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Abstract

Speed, whether above the speed limit or too fast for the conditions, is a significant contributor to fatal and serious injuries at curves on rural roads. The driving behaviour of 40 motorists was assessed using an instrumented vehicle. This vehicle tracked driver behaviour through around 200 curves on a set driving route. Factors including speed, acceleration, side force and lane position were recorded for each driver. Details regarding the design elements of the route were also collected, including curve severity, direction (left or right), horizontal alignment, grade and cross slope. This paper provides initial results for driver speed behaviour through different types of curves, and discusses the implications of the findings.

Introduction

Road crashes result in a significant number of deaths and serious injuries every year. The high incidence of crashes on rural roads has been identified in various countries. IRTAD (2010) report figures for fatal crashes, including those outside urban areas in many countries. These range from a low of 46% in Japan, to a high of 79% in Spain, with the average of all countries providing data being 62%. In the UK 58% of all deaths, and 41% of deaths and serious injuries occurred on rural roads (King & Chapman 2010). In the US, rural crashes accounted for 57% of fatalities, despite less than a quarter (23%) of the population living in rural areas (NHTSA 2007). The rate of crashes (per km travelled) was 2.5 greater than for urban roads.

The situation is also similar in Australia. In a review of road safety on rural roads, Tziotis et al. (2006) calculated that 60% of fatal crashes in Australia occur on the rural high speed road network resulting in over 1,000 fatalities per year in Australia, and more than 22,000 injuries. A number of road environment factors were identified as contributing to these crashes, including the road condition, road design, the roadside environment and speed. The predominant crash types identified were vehicles travelling ‘off path’ (i.e. run off road) followed by vehicles travelling in the same direction (e.g. side swipes, lane changes and rear end crashes), and opposite direction (i.e. head-on) crashes.

Curves appear to have an elevated level of risk, producing a significant amount of all rural crashes. For example, Steyer et al. (2000) report that around half of all rural road crashes in Germany occur at curves. Retting and Farmer (1998) report that around 40% of fatal roadside crashes in the US are at curves. A report by the OECD (1999) suggests that relatively high numbers of crashes on rural roads occur at curves when compared to tangents and that run-off-road and head-on crashes at these locations are a particular problem. It was suggested that isolated curves or the first curve in a series are of greatest danger particularly as the result of inappropriate speed and lane position. Cenek et al. (2011) identified that in New Zealand, loss of control on curve crashes represented around half (49%) of all injury crashes in 2009 on rural state highways. That study identified that around 26% of the rural state network is curved (defined as having a curve radius of 500 m or less), meaning that crashes at these locations are vastly over-represented.

Charlton & de Pont (2007) discuss three causative factors that may have an influence on crashes at curves. It is suggested that attentional demand may be higher at curves than on straight roads, and that this is exacerbated by higher speeds. Misperception of speed and curvature, especially on approach and at curve entry, was suggested as another factor in crashes at curves. Charlton & de Pont provide evidence to suggest that misperception of curvature is 'relatively common'. Wooldridge et al. (2003) also suggest that crashes may occur at curves when there is a disparity between the perceived safe speed of the curve, and the actual speed at which the curve can be safely negotiated. They suggest that driver expectation based on prior experience plays a large part in safe curve negotiation, and that fewer crashes occur at curves that conform to driver expectations. The third cause suggested by Charlton & de Pont is that motorists have difficulty maintaining lateral position through a curve, leading to a loss of control.

Turner (2009) identified that speed was thought to be a major contributor to crashes at curves. This study reviewed the types of crashes on rural roads that were thought by police to be caused by speed (typically defined as 'too fast for the conditions' or above the speed limit). This is a relatively coarse measure of causality as often police do not attend the scene of a crash, or when they do, they may have a limited amount of information available to form an accurate judgement of crash causation. However, the most common crash types in order of occurrence were:

- Off path on curve (i.e. running off the road while negotiating a curve)
- Off path on straight
- Vehicles travelling in opposing directions colliding
- Overtaking.

Off path on curve was by far the most common crash type, with around 80% of all rural speed related crashes. Compared with 'non speed related' crashes (i.e. where speed was not indicated as a contributing factor) this crash type is also over-represented. In non speed crashes, off path on curve crashes accounted for only 20% of crashes.

Despite many years of research on this topic, crashes at curves still occur in significant numbers, and as identified above, many are related to speed. In order to explore this issue, a study was undertaken to determine behaviour of drivers through curves. A number of such studies have been undertaken over the last few decades (e.g. Johnston, 1982; Fildes, 1986; Campbell et al., 2008), but advances in data collection technologies now allow more detailed and comprehensive information to be collected. This study utilised an instrumented vehicle to collect continuous data on speed and other behaviour through multiple curves. A number of different variables were collected, creating a rich data source which will enable a range of hypotheses relating to driver curve negotiation to be tested.

The study upon which this paper is based assesses broader issues based on the variables collected, including road design elements, traffic management, driver lane position etc. However, this current paper focuses on initial results obtained on driver speed through high risk and low risk curves.

Method

Data on driver behaviour was collected using an instrumented vehicle. Each driver travelled a set route on their own in this vehicle. A total of 40 male subjects were included, 20 with limited driving experience (less than three years) and 20 with more experience (15 years or more). Males were selected to reduce study variance, but also because this is a higher risk group of drivers. All recruited drivers were unfamiliar with the test route.

The vehicle was fitted with devices to measure speed, acceleration/deceleration, side force, GPS location (all collected using ARRB's GipsiTrac and associated devices; see ARRB, 2015), lane position, and distance to vehicle in front (collected using a Mobileye device; see Mobileye, 2015). Video images of the view in front of the vehicle were also collected.

Subjects were recruited using a variety of means, including social media, and other sources of advertising. Information was collected for each driver, including details on driving experience (including on rural roads), and type of vehicle normally driven. Information was also collected on attitudes to driving through the Driver Behaviour Questionnaire (DBQ; Parker et al., 1995).

The study commenced with subjects travelling 13 km along an urban arterial route to the start of the test route. This allowed a period of familiarisation with the vehicle. Journey time to the start of the route was approximately 16 to 18 minutes. This route had various types of delineation, including centre and edgeline marking throughout the route, and a mixture of advance warning signs and curve advisory speeds at more severe curves. The semi-rural test route itself was 21.9 km, taking approximately 30 minutes. At the end of the route, drivers negotiated a roundabout and returned along the same route. The journey to the start of the test route, route negotiation, and return to the starting point took around 1 hour and 35 minutes.

The route was a hilly area on the edge of Metropolitan Melbourne, and involved a mixture of speed environments. In some locations it passed through small townships, while in others it was quite rural. With the mixed nature of development along the route, the speed limit varied between 80km/h and 60 km/h. A higher speed environment would have been preferred, but this was not possible given study constraints (particularly travel time to the starting point).

There were many curves along the route, some of which were quite severe with high speed approaches. There were 101 curves for each direction of travel, giving a total of 202 curves over the whole route. The start of a curve was defined as the point on the road where the curve radius fell below 1000m, or where the curve changed direction when the radius was already below 1000m. The end of a curve was defined as the point at which the curve increased above 1000m, or where it changed direction.

Data was categorised by the point within the curve. Data for the 40m prior to curve commencement was classed as the 'approach'; the point at which the radius fell below 1000m was the 'start'; the segment between the start and point of curve minimum was the 'to minimum'; the point of minimum radius was 'minimum'; the segment between the minimum and curve end was the 'departure'; and the point at which the curve finished was the curve 'end'.

Calculations were made for each curve (based on data collected) of curve start point, point of minimum radius (i.e. the most severe point of the curve in terms of curvature), curve length, and curve direction. An estimate of curve risk was also calculated. This risk assessment was based on previous literature on this topic. The measure used for this study was based on a calculation of the difference between approach speed and speed at minimum curve radius. This was identified by several prominent studies (Turner & Tate, 2009; Krammes et al.,1995) as the most sensitive measure of crash risk for curves. The 20 highest risk curves, and 20 low risk curves were identified, and included in this study for analysis.

Data was excluded where drivers were following another vehicle, during periods of rain (defined as when the wipers were in use) or when roadside activity was likely to influence behaviour (e.g. pedestrians, road works).

Results

The results presented here relate to driver speed through the different curves, and at different points on approach and through the curve. This includes an assessment of speed against some design elements of the curve; and speed through high risk and low risk curves. An assessment was also made of difference in driving speed between young and experienced drivers. Other factors of interest are being evaluated and will be published separately.

All results relating to group differences are statistically significant at least to 0.05 level unless indicated otherwise (based on t-tests, applying a Bonferoni correction for use of multiple tests).

The first analysis shows the relationship between curve radius and speed (Figure 1). This presents the average speed for each curve (across all drivers). It is clear that as the curve radius decreases, the mean speed reduces. This finding is as expected based on road design guidance, where the relationship between vehicle speed, curve radius, pavement superelevation, friction between tyre and road surface and gravity is well documented (see Austroads, 2010). It is only really below a 100m radius that speeds fall consistently below 55 km/h. From this point there is a sharp reduction in speeds, to a low of 30 km/h with a radius of 20m (quite a severe bend).

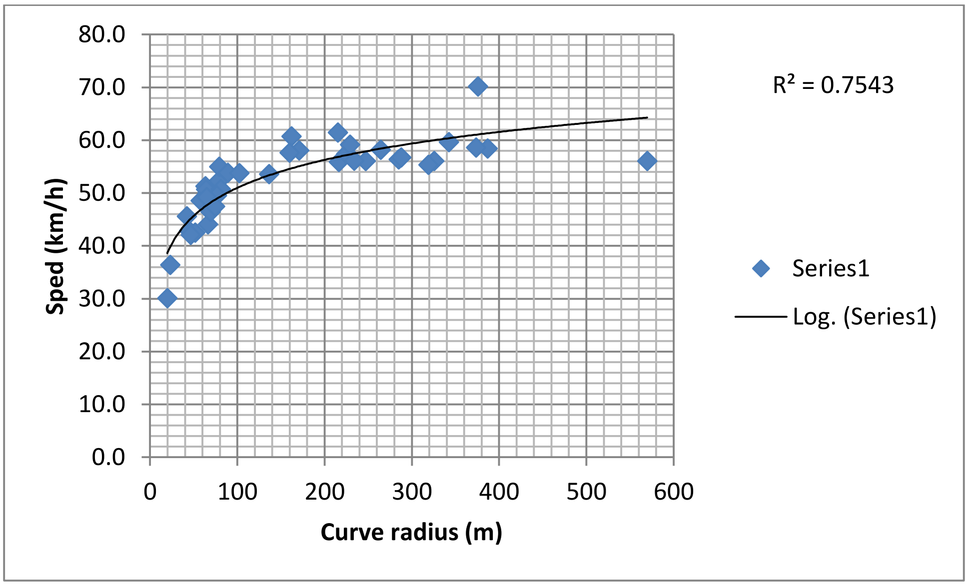

Figure 1. Mean speed by curve radius

Figure 2 shows the speed reduction that occurs from the start of the curve to the point of minimum curve radius. Again, there is a clear relationship between radius and the speed behaviour, with the greatest reduction in speed occurring for the most severe curves.

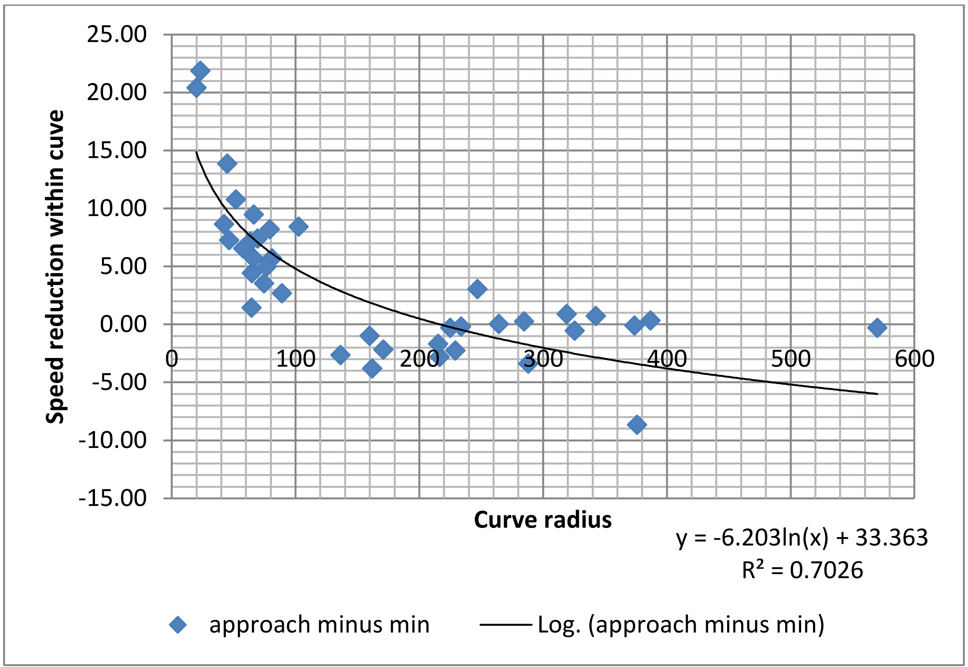

Figure 2. Mean speed reduction by curve radius

Figure 3 shows the reduction in speed based on the calculated crash risk of the curve (defined as the difference in approach speed, and the speed at the point of minimum curve radius).

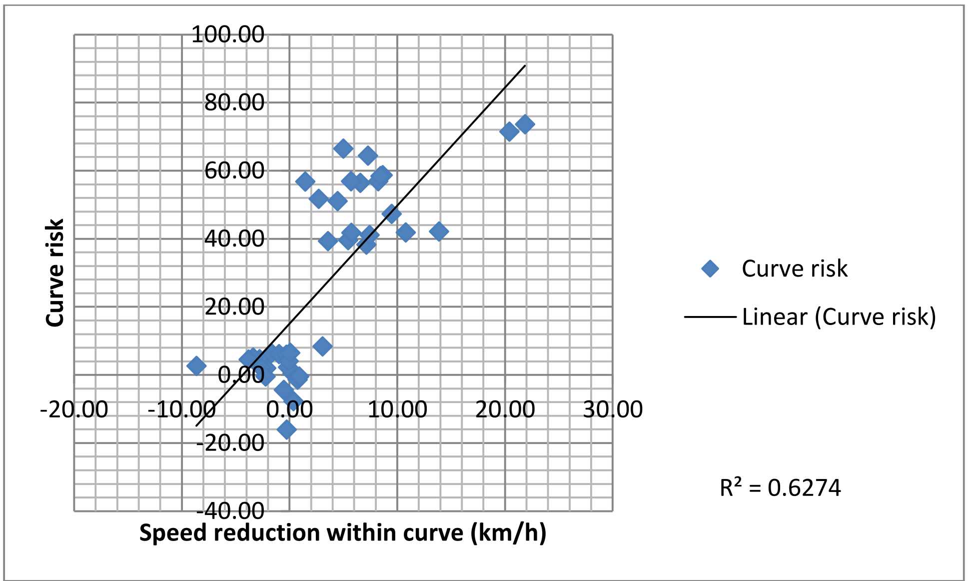

Figure 3. Mean speed reduction by curve risk

Although there is a broad trend for greater speed reduction with higher risk, the relationship is less clear than for curve radius. The two categories of curves (low and high risk) can be clearly observed. Within each of these two groups there is a degree of variance, indicating that although there is a relationship between speed reduction and risk, this is not clear-cut within the two types of curve.

The next set of analyses show speeds at different points throughout curves, comparing high and low risk curves. Mean speeds were lowest through the high risk curves (52.3 km/h compared with 58.5 km/h). Speeds are lower at all points through the curve, with the minimum speed coinciding with the point of minimum curve radius, as shown in Figure 4:

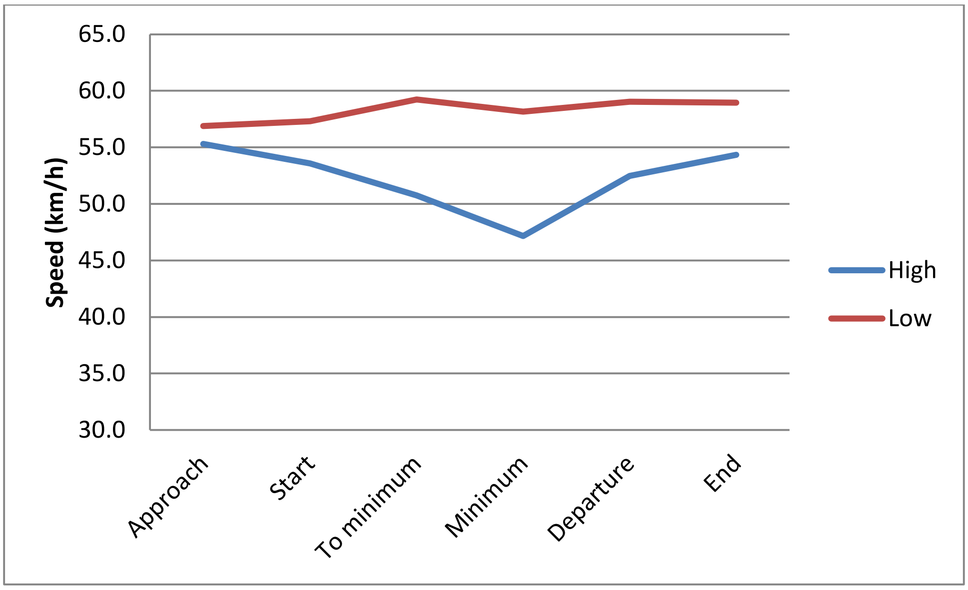

Figure 4. Mean speed by curve risk type

On closer analysis, several things are apparent. For the high risk curves, it appears that speed reduction may have commenced in advance of the 40m buffer used in this analysis, given the mean speed at approach is lower than for low risk curves. It is also apparent that speeds had not returned to the pre-curve level at the end of the curve (10m beyond where the curve radius exceeded 1000m).

A separate analysis was conducted for left versus right curves. This can be seen graphically in Figures 5.

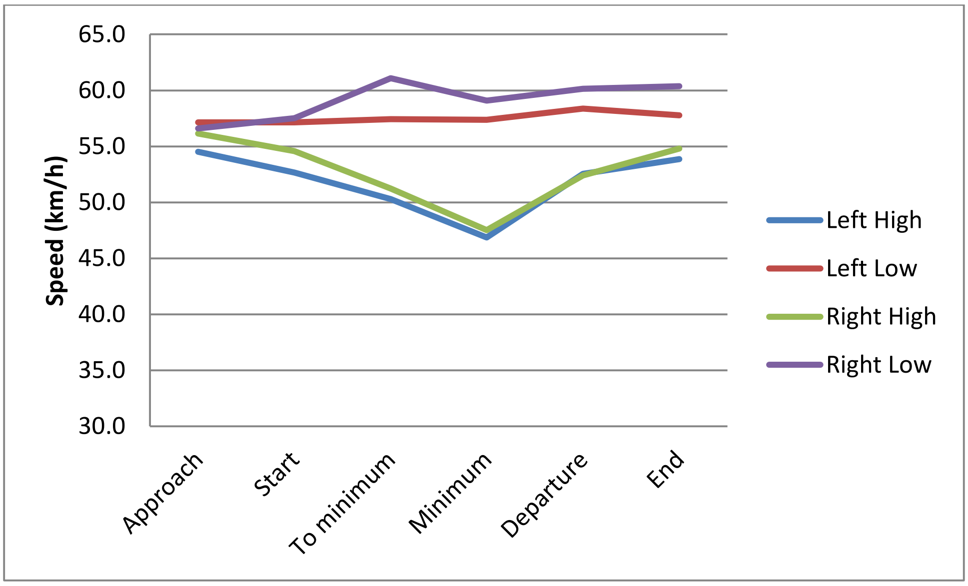

Figure 5. Mean speed by curve risk type and direction

The driving behaviour for both left and right curves was similar, although it is clear that speeds are higher for right curves than for left for both high and low risk curves. For high risk curves, the higher speeds occur when approaching the curve minimum (differences were not statistically significant at minimum, departure or curve end).

Given that speed data is continuous (i.e. gathered every few metres along the roadway) and information was also available on elapsed time for each driver, it was possible to make an accurate calculation of vehicle acceleration and deceleration. Figure 6 shows the result for (a value above 0 m/s/s) and deceleration (values below 0 m/s/s) through different types of curves.

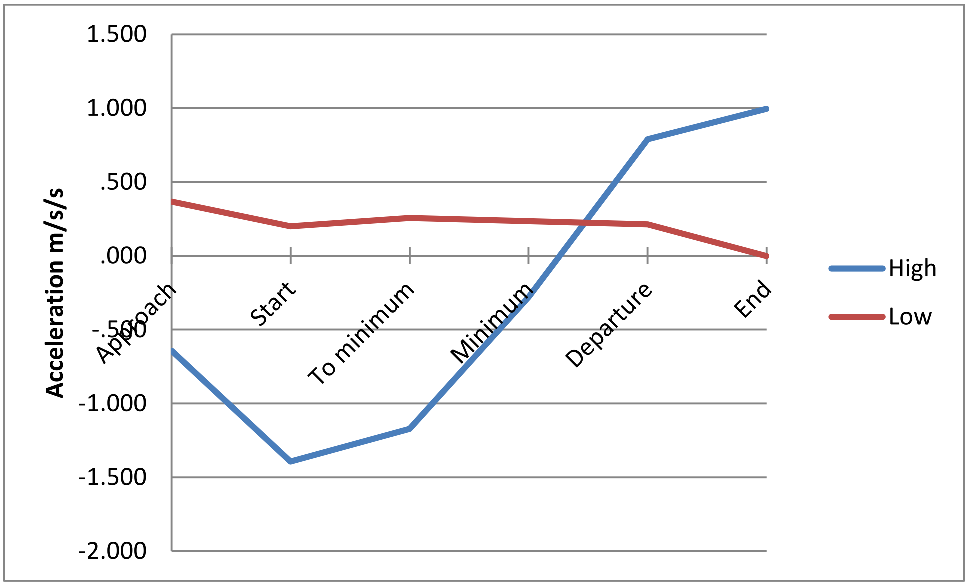

Figure 6. Mean acceleration/deceleration through curves of different risk

It is clear that deceleration has commenced in advance of the curve approach point for high risk curves, and is at its maximum level at curve start. Deceleration continues on approach, and beyond the point of curve minimum. Vehicles are accelerating at curve departure, and continue to do so through curve end.

Lastly, a comparison was made between driving speeds of young drivers and experienced drivers. Figure 7 shows that there is no clear difference in speeds based on driver experience. Although the results were statistically different (except at the point of curve minimum), the results were not at all substantive, particularly for the high risk curves

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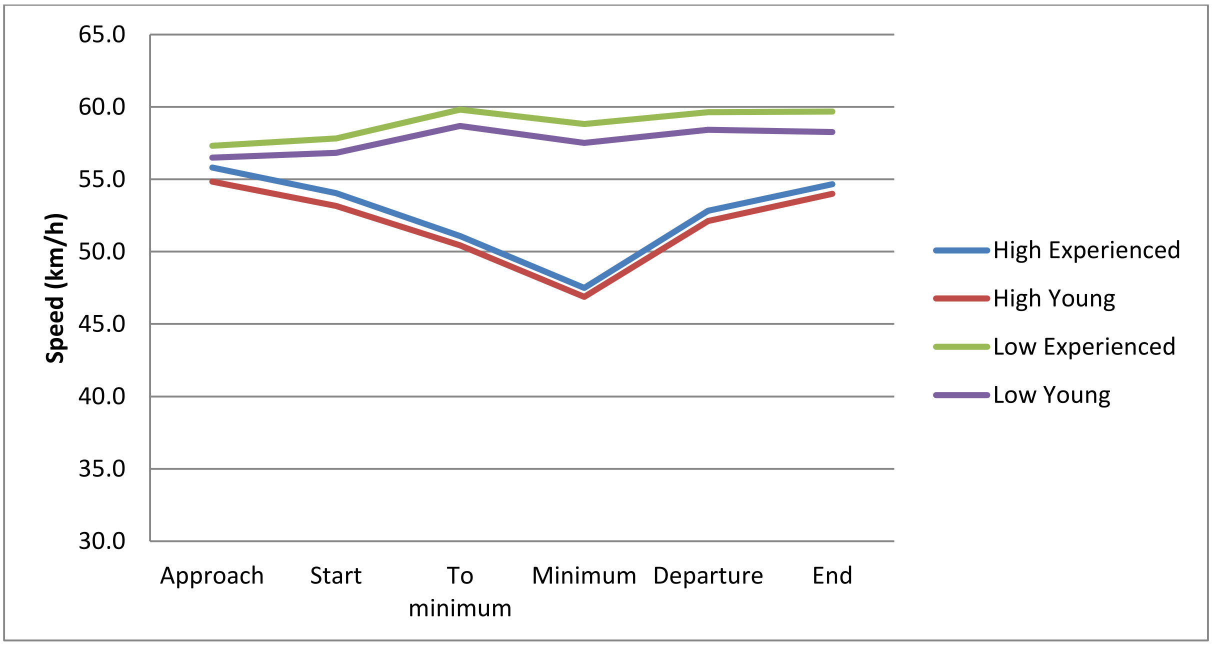

Figure 7. Mean speed by driver experience

Further analysis has been undertaken on difference by driver experience for other driving behaviours, and will be reported in future.

Discussion

It appears that driver selection of speed through curves is highly correlated to curve radius. Drivers seem highly attuned to this element of curve design when making decisions about an appropriate speed. However, it was also noted that these reductions only really commence below a curve radius of 100m. This is interesting, as although risk is greatest for curves below this radius (Veith et al., 2010 suggest the risk is six times greater than for straight roads), there is still a greatly elevated risk for curves with a greater radius (i.e. a less severe curve). The risk for curves with a radius of less than 400m is double that of straight roads, and as highlighted by Levett (2005), curves in this band are far more common, and may (in aggregate) form the greater risk for drivers. Measures to highlight the risk for curves of less than 400m, and the requirement for speed reduction, would be desirable. Jurewicz et al (2014) suggest that categories of curve should be defined based on risk, and differential forms of delineation used for individual curves depending on this category. The findings from this study tend to support this approach, with different curves likely to require different methods for highlighting severity and the appropriate speed.

Speed reduction based on curve risk was less clear-cut within the two broad risk bands (high risk and low risk curves). Within the high risk curves, the amount of speed reduction from curve start to curve minimum was relatively independent of curve risk. This may be because speed reduction had already commenced well in advance of the curve. It would be possible to assess this issue with further analysis.

Speed patterns within curves were as would be expected. Speeds were lower at all points for high risk curves, and the lowest speeds (at least when broadly banding curve segments) occurred at the curve minimum. The result indicating higher speeds through right curves is interesting. Right curves are known to have higher risk (Kloeden et al., 1997; Levett, 2005), a finding that was confirmed from an analysis of crashes on the test route. In an analysis of crashes from the VicRoads crash database (VicRoads, 2014) it was identified that 55% of crashes at curves occurred at a right hand bend. The higher speeds at right hand curves therefore deserves further attention to determine additional risk factors, and to help to identify the means to address these.

One particularly interesting finding from this study was that deceleration continued through and beyond the curve minimum point for high risk curves. Given this is a high risk location it is highly desirable that drivers will have already fully decelerated by this point. Although there are some indications from previous research confirming this finding, road design standards assume that speed reduction is complete at curve start, let alone at this point later in the curve (Austroads, 2010). This finding could have implications for design guidance. Further analysis is required to determine the situations (e.g. the types of curves) where this issue is most prevalent. Given the data set created through this study, this is very feasible. Mechanisms to ensure speed reduction is completed before curve minimum would most likely reduce crash risk. Options need to be explored regarding how this might best be achieved. Such options might include signs located further in advance of curves.

The result indicating no substantive difference for different drivers with different levels of experience is interesting. It could have been expected that young drivers would have exhibited higher speeds, especially through high risk curves, given the higher risk of this group. The opposite was observed in this sample, as young drivers showed lower speeds at all points through both low and high risk curves (the only exception being at the point of minimum curve radius for high risk curves where there was no statistically significant difference). It may have been that young drivers were more cautious in this sample because they were being monitored, or that they are more cautious in selection of speed through curves in general (at least from short exposures to rural driving). Given that some quite extreme behaviours were observed in the sample (e.g. very high speeds and side force by individual drivers through individual curves) despite being observed, it is possible that both situations may be true. It is possible that issues in addition to speed selection are significant in the elevated crash risk of young drivers.

There are a number of limitations to this study. These include that drivers were driving in an unfamiliar vehicle, and were being 'observed'. Despite a period of familiarisation prior to reaching the test route (and some settling of behaviour towards 'normal'), it is possible that drivers were not performing as they normally would. Secondly, the driving route in this study was a constrained hills environment with a maximum speed limit of 80km/h. Although some quite severe curves (in terms of the required speed reduction) were able to be included in the study, analysis of a higher speed environment would be desirable. Thirdly, there are a number of elements that differ between curves, including traffic management and delineation (such as presence of advance warning signs and chevron alignment markers). Although the large number of curves included in this study will compensate for such differences to some extent, it could be expected that these elements will also have an impact on driver selection of speed. Further analysis including these elements is required to help determine their actual impact.

Due to these limitations, generalising of the findings from this study to other contexts should be done with caution.

The data set created through this study will continue to be explored, including the analysis of other behaviours. Assessment of side force and lane position will be important to more fully understand driver behaviour through curves, as will the relationship between these variables and speed. This additional analysis will be presented in future.

Acknowledgements

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The Future of Road Safety in a Technological World – How will technology impact the practice of Road Safety?

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Abstract

Over previous decades, road safety practitioners have delivered significantly safer roads through improvements in vehicles and by deploying countermeasures designed to reduce the risks that may be taken by a driver. Education and enforcement have sought to reduce driver risk taking, especially in areas of speed and drug and alcohol use. Behavioural studies and research data have provided evidence of the efficacy of various programmes and produced effective policy. Technology applied to vehicles has primarily focused on reducing injury severity in the event of a crash.

A new wave of technology is now upon us that is unlike previous technology. This new wave of technology seeks to further reduce the risk of fallible drivers by providing them with alerts or even bypassing them completely and controlling the vehicle to avoid a crash. Current systems of this type include Adaptive Cruise Control and embryonic Collision Avoidance Systems.

This wave has the potential to be game changing and very disruptive. The role of the driver is likely to change and ultimately there may be no need for a driver at all.

This paper examines what the future might hold for road users and presents a number of research questions for the Australian road safety community to consider. Discussion will include current technology, how the role of the driver may change, question how driver education may change, and what new risks might be introduced. This discussion will include a reflection on the practice of Road Safety with a changing road system.

Introduction

Safety on our roads has been a battle fought for decades. The ability of road safety practitioners to tackle road safety is often reliant on technical and technological improvements to vehicles, and to understanding and modifying driver behaviour. Two significant initiatives that have had great success locally are mandatory seat belt wearing and various programs to curb drink driving.

In this paper we reflect on previous great work of the Road Safety community. We then explore how current and future vehicle technology might impact on the current and future role of the driver. As we do this, we consider how these changes might impact on the current and future work of the Road Safety community.

Past and Current Road Safety Efforts (with a focus on vehicles and drivers)

The history of the practice of road safety is full of technological and practise innovations that have contributed significantly to the safety of road users. Vehicles themselves have changed appreciably over the decades. With a focus on crashworthiness, improvements in vehicles have reduced deaths and serious injury in the event of the crash. The modern vehicle is now designed to absorb energy and redirect forces away from occupants and tales abound of amazing "escapes" by occupants in

[1] NICTA is funded by the Australian Government through the Department of Communications and the Australian Research Council through the ICT Centre of Excellence Program.

crashes at significant speed. Modern vehicles are clearly the best designed in history for protecting occupants in the case of a crash. However the market is showing signs that further improvements face the law of diminishing returns. Given fundamental physics, it is hard to see significant improvements in crashworthiness.

On a different front, significant progress has been made in understanding the driver's role in controlling a vehicle and mitigating risks that arise from having a human in control of a vehicle. Our understanding of how alcohol and drugs impair drivers and increase the risk of a crash has increased significantly. With a focus on education and enforcement, the previously entrenched behaviour of drink driving is now socially unacceptable and only practiced by a minority. Random breath testing in Australia has a clear correlation with a reduction in the road toll.

Speeding has also been a significant issue for road safety practitioners. While vehicles have improved significantly in their ability to absorb or deflect energy in a crash, fundamental physics cannot be escaped. The faster a vehicle goes, the more energy it carries, and the more energy that needs to be dissipated in a crash. Over the decades, the understanding of the risk of speed to the driver, vehicle occupants and other people sharing the road environment has matured. The consideration of appropriate speeds for driving environments has become an objective, evidence-based process. This is well understood within road safety and government circles, but perhaps unappreciated by many drivers.

Other initiatives target young drivers who are more likely to take risks. Elderly drivers are also known to present additional risks. Physical ailments and slowing cognitive abilities diminish an older driver's ability to react in emergency situations. Countermeasures such as testing older drivers and educating younger drivers are widely used to mitigate these risks.

Current Focus of Road Safety Practitioners

The past partly explains the current focus of road safety practitioners. If the program for the Australasian Road Safety Research, Policing and Education Conference, 2014 is an indication of the current focus of road safety, then current efforts have a strong focus on the driver. Topics such as young drivers, older drivers, driver impairment, speeding, driver behaviour, enforcement and education featured strongly. While areas such as road conditions, infrastructure, vehicle improvements and technology were present, the current focus is rightly on the role of drivers and the risks they introduce to the road system.

However, possibly the most significant recent innovation in road safety is the realisation that human error is inevitable. The *Safe Systems* (RTA 2011) approach to road safety recognises human error as unavoidable and the entire road system needs to mitigate the risk introduced by human error—especially driver error. This is something that technology has already started to address.

Recent Technological Improvements and Trends

A large array of technologies have recently become available in production vehicles. These include the following (Thakuriah & Geers, 2013):

- Adaptive Cruise Control (ACC)*
- Emergency Brake Assist *
- Forward Collision Warning
- Autonomous Emergency Braking *
- Electronic Stability Control (ESC)*

- Lane departure warnings
- Lane keeping assist *
- Curve assist *
- Rear view cameras
- Reversing proximity sensors
- Automatic parking *
- Blind Spot Detection
- Daytime running lights
- Cornering lights
- Auto-hold

This list may be divided into three functional groups.

1. Vehicle visibility enhancement for driver or nearby vehicles
2. Alerting the driver of potential threats to the vehicle
3. Automation. (*) Take control of the vehicle

In many cases technology starts out offering driver alerts and then evolves into a fully automated offering. For example, forward collision alerting evolves naturally into autonomous emergency braking. This appears to be a trend (which has both economic and technological components). As the technology in a warning system matures, a second generation of the technology emerges where these systems take control of the vehicle by braking, accelerating and even steering. In the extreme, we have Automatic parking where the driver engages the system and takes only small actions while the vehicle largely parks itself.

However it is worth consider that in mitigating particular risks, each of these technologies introduces new risks especially in how a driver interacts with the vehicle. Let us consider some of those in the light of currently available technologies.

Alert Based Systems

Many technologies are initially offered as alert based systems. In these systems an audible and/or visual alert is generated to inform the driver of a potential risk. Examples include Forward Collision Warnings, Lane Departure Warnings, and reversing proximity. While the technology might partially or even fully mitigate the targeted risk, the process of generating an alert and having the driver react to the alert introduces new risks.

Of particular concern with an alert based system is providing the alert in time for a driver to react and take appropriate action. To compensate for reaction time, an effective alert system needs to provide an alert that allows time for the driver to react to that alert. However, the earlier a prediction of a threat is made the more uncertain that prediction. Other events may occur to remove the potential threat. Many situations that look like a potential threat at a large time horizon resolve without incident. To the driver, any alert that does not resolve to a true threat will be perceived as a nuisance alert.

The manufacturer of the alert system has to decide whether to generate alerts for all situations deemed a potential risk at the necessary time horizon but with the strong likelihood it will result in an increased occurrence of nuisance alerts, or do they reduce the time horizon to decrease the occurrence of nuisance alerts at the cost of a higher likelihood of negative outcomes—albeit with possibly reduced severity. Nuisance alerts pose an issue for the driver who has to determine their importance. They could be expected to be more casual in their response to the alert taking more time to take action, and potentially increasing the severity in the case of an alert before a crash. In systems that produce few nuisance alerts, the reverse situation is possible. A driver simply may not be exposed to the alert sufficiently to remember what it means or what action to take. So when a real alert occurs, the driver may not react in an appropriate way.

These concerns lead to the following questions:

- How affective is an alert / warning system?
- Do warning systems prompt a correct response from a driver?
- What is the effect of a significant number of nuisance alerts on driver behaviour to future alerts?
- How do drivers react to alerts that are infrequent and/or unfamiliar?
- What effect do multiple alert types have on a driver? How many alert types can a driver handle before becoming confused (cognitive/mental overload)?

A number of these issues have already been partly considered but the potential increase in warning systems may make this even more significant. For example, mental overload (Young & Lenné, 2013; Hancock & Parasuraman, 1992) may become an even more significant issue as a driver deals with alerts from multiple systems.

Automated Systems

Automated systems avoid a number of issues seen in alert based systems. With the vehicle taking action automatically, the driver is seemingly out of the loop. At first consideration it might seem unlikely that there are driver based risks. However, current automated systems either control the vehicle for a short period in response to a threat, or require the driver to manage and control the automated system itself. For example a driver sets the speed for cruise control. In systems that take control of a vehicle for a short period (such as Autonomous Emergency Braking or Lane Assist) the period of autonomous control can be timed in seconds. By briefly wresting control from the driver such systems clearly aim to mitigate against human error.

There are a number of risks posed by short period automation systems that are illustrated by the following questions:

- What are the limitations of the technology and do drivers understand those limitations? When might the technology fail to operate – especially when the driver is relying on it?
- Do drivers understand the technology?
- What are the effects of an intervention on the driver's ability to subsequently control the vehicle? For example, might they be shocked or scared by a "close call"?
- Is there a risk that a driver might come to rely on the technology? Could a driver become more aggressive thinking they will be saved by the technology?
- Might a driver of another vehicle act in a way that relies on the technology or take additional risks? For example, cut in on a vehicle with Autonomous Emergency Braking. (See Adell et. al., 2011; Young & Lenné, 2013)

- Could the technology hand control back to the driver (or the driver take control) when the vehicle is in a state that is difficult to handle—especially if the technology has been controlling the car close to the edge of its performance envelope?

Other automated systems such as adaptive cruise control and automatic parking perform tasks previously undertaken by the driver. These technologies appear as though they remove a task from the driver. However, these technologies ought to be viewed as tools requiring management and supervision as they control the vehicle. So rather than control the speed through use of accelerator and brake, the driver can control the speed through the use of the adaptive cruise control. In essence the driver is still in control.

One potential significant risk of automated systems is a loss of situational awareness. As the driver is now monitoring the control of some primary controls, a disconnection could occur between the driver and those primary controls. A slow degradation in conditions could go undetected by the driver because they do not have direct input into the control system. The adaptive cruise control and traction control systems could drive into these worsening conditions until a point is reached where the vehicle cannot be controlled in the conditions.

These kinds of issues pose some risks and another set of questions:

- How well do drivers understand the technology, especially in transition between handing over control and taking or receiving back control?
- Are there limitations to the technology and times when it might not work?
- Could the technology lead the vehicle into a dangerous situation without the driver becoming aware?
- Do drivers recognise the need to manage the vehicle and oversee the technology or do they “set and forget”? (See Totzke et al, 2011; Young & Stanton, 2007)
- Could the automated system hand control of the vehicle back to the driver in a state that is essentially uncontrollable?

Driver Resists Use

A new technology is of no use if a driver chooses not to use it or disables it. Anecdotal evidence suggests technology can be disabled due to drivers’ frustration with that technology. Nuisance alerts and perceived false activations of technology seem a common reason and are possibly caused by differing driver risk profiles. It could also be caused by a failure of the design of the technology to consider other factors, such as different vehicle performance when ascending or descending a hill.

A number of issues present an impediment to the adoption of risk reducing technology and raise questions similar to earlier ones such as:

- What factors might cause a driver to disengage or fail to use a technology? What countermeasures are required?
- How well do drivers understand the technology? Do they require training or to be educated about the use case for the technology?
- How do driver’s perceptions of risk differ between when they have control and when technology is enabled? Does evidence support or contradict those perceptions?

Future Technological Improvements and the Role of the Driver

It seems likely that a number of current technological improvements will be pushed further on the path to a fully automated vehicle. Lane assist and curve assist for example are likely to be refined to lane keeping and curve following. With these technologies once a vehicle is set up on a road, it may not require further input on the steering wheel for significant time and distance. Combined with adaptive cruise control, in some environments a vehicle would be capable of covering large distances and operating for a significant period of time without driver input.

Additionally a number of other new technologies are likely to reach vehicles in the next decade. Dedicated Short Range Communication (DSRC) allows vehicles to talk to each other, potentially providing information that is beyond the range of the driver's senses or the vehicle's sensors. These systems can provide alerts of potential collisions from all geometrical aspects. They can also warn of rapidly slowing traffic ahead. Communication with infrastructure can give drivers information on signal timing at an intersection, lane closures, and hazardous conditions. As communication systems mature, it is reasonable to expect alert systems to be replaced with automated actions. Vehicles might automatically brake to avoid collisions, or negotiate a mutually agreeable resolution with each other.

While the authors anticipate a longer time horizon to the fully automated vehicle than is often cited by technology evangelists, it is clear that the next decade will see significant automation introduced in production vehicles. This raises some significant questions regarding the role of the driver and new risks that this technology might introduce.

Driver's Role

There is a fundamental difference between today's automated technology and that likely in the future. Today's automated technology, such as adaptive cruise control, lane keeping assist and curve assist leave the driver in control. It is assumed that while using these technologies, the driver is managing and monitoring those systems to ensure they deliver the desired outcomes. The driver is not out of the loop but rather performing a modified role of managing technical systems that are driving the vehicle.

However, there is a strong risk that as vehicles become more automated, the role of the driver will become confused and poorly defined. As technology takes over the traditional role of acceleration, braking and steering, the driver's role in future vehicles will change from handling these primary controls to managing and monitoring systems that control those primary controls. Initially it would be expected that while no input by the driver will be required during normal operation in uneventful and controlled environments, the driver will continue to assess the environment for potential threats that may require manual intervention.

This poses a number of additional research questions:

- What role is a driver likely to play in a highly automated vehicle?
- If a driver's role becomes one of monitoring vehicle systems and reviewing the vehicle environment for threats, how good are they likely to be at this?[2]
- What training if any should a driver have to understand and manage an automated vehicle?
- Does this different driving method require licence endorsements?
- What level of attention should a driver pay to the performance of automated functions?

[2] S Bainbridge (1987) indicates humans are not good at monitoring. Martens & van den Beukel (2013) discuss driver cognition being increased by monitoring an automated action.

- What level of attention should a driver pay to the outside environment?
- How should automated functions take over driving and pass control back to the driver?
- In a highly automated vehicle, can automated technology assume a driver is always available to take back control of the vehicle?

In considering the vehicle of the future, there are particularly interesting issues when a vehicle is in an environment where it can drive itself without the driver even monitoring the vehicle or environment. Further questions ought to be considered such as:

- If the vehicle can manage all environments, does the vehicle need a driver?
- Does the 'driver' need to be physically present in the vehicle or could a remote driver control the vehicle?
- What environment is required for safe operation? Can the technology handle pedestrians, broken down vehicles, cyclists, animals….
- Is it realistic to expect a driver to resume control when the environment is no longer appropriate or when a situation evolves that the vehicle's technology cannot handle? What kind of time notification to the driver should be required?
- Should regulators require a vehicle with such a technology to always be in a position where it can bring the vehicle to a complete stop in a safe environment?

Much of the talk in automated vehicle circles assumes that an automated vehicle would be able to "hand off" to the driver. Is this a realistic expectation? What are the potential risks raised by the assumption to be able to hand control back to the driver?

Perhaps the greatest risk is that market forces result in systems being deployed without proper consideration and research effort being given to these issues.

The fully connected automated vehicle

Again considering the vehicle of the future that is fully automated and able to handle many different types of environment. It is also connected to the road system. No longer is the vehicle an independent entity but a fully connected part of a distributed system. In this scenario a driver is not required in the vehicle. The road system is the driver and where manual intervention is required, it comes remotely or the vehicle is shut down and personnel are dispatched to the location.

Unlike today, the driver would no longer be a risk. So what are the risks? In this future environment, it will be users of other spaces close to the road system, or people who interact with the road system. It will be cyclists and pedestrians. It will be children in a park running after a ball onto the road. People will still make errors.

Changes and Impact on the Practice of Road Safety

Considering all that has been presented above, the ultimate question for the Road Safety community is: If the role of the driver changes, what will the new significant issues be and how might Road Safety change? As an example, it is worth noting that even today speeding could be rendered technically impossible in all new vehicles. That in itself would significantly change the face of Road Safety.

However, the most significant future changes are in the role of the driver. So what steps ought to be taken to mitigate the risks associated in the change of role of driver? Education surrounding the new technology, how it works, why it should (or even must) be used, how to use it, and its limitations are all aspects that are currently lacking in the as new technology is introduced. There are areas that the Road Safety community should consider investigating.

Additionally there will be new areas to focus on. As drivers progressively present less risk in the road system, interaction of vehicles with pedestrians, cyclists and other road users are likely to become far more important.

Also while this paper has not addressed potential legal issues (and it is beyond the expertise of the authors), a number of issues are anticipated and these may be barriers to the introduction of technology with a significant safety benefit. For example, there are a number of areas where the driver is currently liable but where in the future technology makes this unreasonable. This area becomes particularly interesting when vehicles are acting based on trusted information from a third party. Potentially some significant work will need to be done in policy, regulation and law making.

Conclusions

Road safety has come a long way during the last several decades. Previous technological improvements have resulted in cars that are significantly more crashworthy than their predecessors. Road Safety practitioners have also focussed on the driver, a human who may err. Currently one of the greatest overall risks in the current road system is the driver.

Vehicle manufacturers are introducing a swathe of new technology designed to mitigate risks associated with common errors in human drivers. Autonomous Emergency Braking, Lane Assist and Curve Assist all seek to address situations where a driver has failed to take appropriate action to a risk.

Looking to the future, there is a wave of new technology descending on vehicles. This wave not only seeks to mitigate errors of human drivers but is likely to ultimately replace them. During this process, the role of the driver will change. This paper has sought to highlight those possible changes and provide questions for the Road Safety community to consider as it faces a wave of technology that will change the role of the driver and the whole road system. There is significant work to be done and the authors hope this paper helps Road Safety Practitioners consider the future of Road Safety.

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Study of current factors affecting road safety for 16 – 18 year old novice drivers in the Wingecarribee Shire

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Abstract

Young novice drivers in the first six months of their provisional licence phase have higher crash and fatality rates which are disproportionate to other road users (Bates, Watson & King, 2006). The 'Rotary U Turn the Wheel' road safety program was developed to educate novice drivers of these risks, changes in attitude and behaviour, and to support the school curriculum in this area of road safety.

Approximately 822 Year 11 students across the Wingecarribee Shire whose ages range from 16 – 18 were surveyed during the 2013 – 2014 period at the annual 'U Turn the Wheel' event. The survey aimed to benchmark issues and factors that impact both positively and negatively on road safety for 16 – 18 year old novice drivers. The survey was anonymous which allowed students to candidly discuss issues that effected their driving experiences as well as personal issues that may also affect road safety in this vulnerable group without fear of any negative consequence.

Factors discussed in the survey included their involvement in accidents or infringements, high risk behaviours, media advertising and its effect, personal drug use, medication, as well as any medical issues that could affect their driving ability.

The study results will form the basis of an educational review of the U Turn the Wheel program to ensure best practices are employed in the program and teaching content is current and relevant to the target audience.

Keywords

Road safety, novice , drivers, U Turn the Wheel, young driver issues, road safety education, risk factors, student survey.

Introduction

Driver education programs are often developed through community response to local road trauma and have been the subject of various studies to establish the effectiveness of the programs' ability to reduce a driver's crash risk. Little evidence has been established to link driver education attendance to lowered crash risk for participants (Bates et al. 2006) and may contribute to the short term nature of the program which has a dilution effect on participants when compared to the extended influence of supervising drivers and/or parents. Drivers aged 17 – 24 years are 3 times more likely than other road users who are over 21 to be involved in a serious crash (NRMA, 2015).

This preliminary study identifies the factors that affect the road safety of young novice drivers who attended the *U Turn the Wheel* program during 2013-14. It uses the information obtained to perform an educational review of the road safety program and also compares program content with actual audience needs.

The Rotary Club of Moss Vale together with the Wingecarribee Shire Council Road Safety Officer established the initial *U Turn the Wheel* program which is now duplicated in many other areas. The program was based on the principle that “road safety is a community problem which demands a community solution” (Faulks et al. 2008). The program relies on the commitment of the Roads and Maritime Services, local council road safety officers, schools, road safety experts as well as the wider community of volunteers that make it a success. In 2005, Redshaw reviewed local programs including *U Turn the Wheel* and found that overall “students are receptive to information that they see as directly relating to them”. It was necessary to compare what this age group thought was important in regards to road safety and what was actually being taught during the sessions of *U Turn the Wheel*. For any educational program to be effective, it is necessary to establish relevance of the content to the participants and their current situation. The survey allowed participants to voice their current concerns and issues in relation to road safety issues relevant to their needs.

Methods

The current *U Turn the Wheel* program in the Wingecarribee Shire is a compulsory program for the local high schools. The program is run once a year from August to November and all Year 11 students are required to attend. In late 2013 and early 2014 schools were given a copy of the survey to be completed during the program and its inclusion was added to student information sheets.

The survey was developed to cover a wide range of road safety issues and was then reviewed by a research and marketing consultant to ensure the wording and questioning style was clear, concise and measurable. The survey was anonymous which allowed students the freedom to express their honest views and opinions to questions. Results could not be attributed to any particular school, gender, socio economic group or locality other than the broader Wingecarribee Shire area.

The hard copy survey was distributed and students were given time to complete and hand it in during the final plenary session of the day. Participants had just completed five hours of road safety seminars and had developed an initial understanding of the issues and effects within the community. Surveys were collected and collated without bias.

Participants (n= 822)

The participants in the survey were Year 11 high school students from a wide variety of socio economic backgrounds, ethnicities, gender and localities within the Wingecarribee Shire. The participants were aged 16 – 18 years of age. A high percentage of participants held a current learner or provisional 1 drivers licence, class C. No participants held a provisional 2 class C licence.

Survey areas:

Students were asked a range of questions both in multiple choice/ tick the box as well as short answer responses. The questions were grouped into the following categories:

- Licencing: type held, time period, offences, logbook compliance, driving lessons
- Low risk strategies: head checks, indicators, speeding, CAS, seat belts, mobile phones
- Drugs: medications taken, medical issues
- Road safety advertisement: memorable advertising

Results

Licencing:

Year 11 students ranged in age from 16 – 18 years of age. It was expected that the majority of students would hold a learner licence. 822 participants were classified into licence type.

The survey results were further subdivided into the length of time the participant held the current licence class. The results showed the largest group of participants had held a learner licence for 6 – 12 months and provisional 1 licence holders had held the licence for 1 – 6 months.

The program achieved the aim of delivering a road safety message to the most vulnerable group of novice drivers – learners and provisional 1 licence holders. Provisional 1 drivers are at higher risk than any other road user group in the first 6 months of driving. The program has achieved a capture point of learners holding the licence for 6 months or more and provisional 1 licence holders in their first 6 months of solo driving experience. (Table 1)

Table 1. Main capture point of participants by licence type

Percentage per Licence class	**No licence 15%**	**Learner 75%**		**P1 10%**		**P2 0%**
Capture point		First 6 months	Last 6 months	First 6 months	Last 6 months	
	15%	26.5%	48.5%	7.8%	2.2%	0%

Licence holders were asked if they had received any traffic offences during their learner or provisional phase up to and including the day of the program being held. The main fines and or penalties listed were for the following offences:

- Speeding 9.2%
- Driving without a supervisor 5.3%
- Not displaying their P plates on the vehicle 3.4%
- Accidents (minor) 3.3%

A small percentage of participants had been fined for negligent driving which could be attributed to the identified minor vehicle accidents in which they had been involved.

The participants had been asked how many demerit points they had lost whilst on their licence; the results did not correspond with the previous answers relating to offenses which all carried a demerit point penalty. This may be due to the participant's limited knowledge of the current demerit point system and how offences can carry a financial penalty and a related number of demerit points.

The opportunity was taken to question participants on their compliance to logbook requirements. Currently in NSW learner drivers under the age of 25 years must complete 120 hours of driving experience on road, with a minimum of 20 night hours. Learner driving hours are recorded in a Roads and Maritime Services (RMS) logbook which is signed off by their supervising driver to verify the learner has actually completed this time. Non-compliance or defrauding the logbook constitutes an offence which if caught, will incur a penalty, possible criminal charges as well as being refused a driving test for a set period of time.

In order to clarify their actions and demonstrate what happens in reality, participants were asked “When you sat your P1 test did you actually complete the full 120 hours in your logbook?” They were given a Yes /No selection. Those who answered ‘No’ were asked to identify if they had completed 80 – 120 hours, 50 – 80 hours or less than 50 hours in their logbook.

The majority of drivers on provisional licences answered ‘Yes’ to completing the required 120 hours. Of the drivers who did not complete 120 hours, the results were listed as either 80 – 120 hours or under 50 hours. No participants had answered 50 – 80 hours. The majority of participants had completed between 80 – 120 hours in their logbook before sitting the practical driving test.

Learner and provisional drivers were also asked if they had undertaken paid driving lessons with a professional driving instructor. (Table 2)

Table 2. Hours of professional driving instruction undertaken

No lessons	***1-5 hours***	***5-10 hours***	***10 or more hours***
48%	26.5%	14.8%	10.7%

The majority of participants holding a licence had not yet undertaken formal professional driver training. Of those participants who had undertaken professional lessons the highest percentage had completed 1 – 5 hours of professional training. Overall the time learners were exposed to professional training was less than 5 % of total training time (120 hours). This left parents/supervisors to ‘fill the gap’ of 95% of training with limited support of correct training methods, current information and road rule knowledge. This skills gap for both the learner and the supervisor needs to be addressed as a priority to reduce the potential transfer of incorrect knowledge and skills to new novice drivers which may affect the road safety of this vulnerable group of road users.

Low risk strategies:

Participants were asked a variety of questions that related to the implementation and compliance of low risk strategies whilst driving. The main areas were seat belt compliance, head checks or blind spot checks, indicating off roundabouts, implementing a 3 second safety gap (crash avoidance space – C.A.S), speeding and mobile phone usage.

Whilst seat belt compliance is relatively high in Australia, recent years with increased immigration from countries where seat belts are not heavily enforced has seen the compliance figure reduce slightly. An educational campaign has been developed to educate these immigrant groups to ensure their understanding of the safety benefits and risks are fully understood.

Ethnic background was not questioned within the scope of this survey and therefore no result can be obtained for non-compliance to any specific ethnic background.

Participants were asked “Have you ever driven without a seatbelt?”

Compliance within the participant group was relatively high at 80 % but a further 14.1 % did not answer this question. The participants that answered ‘Yes’ to the question were asked if they did this frequently (0.6%), occasionally (4.2%), always (1.1%).

The small number of non-compliant drivers not wearing a seatbelt would be considered too high a risk as these potential accidents have a high risk of fatalities.

Participants were asked if they performed necessary blind spot checks when driving; 51% answered always, 27 % sometimes, 9% never and 3% not completing the question. The issue of positive enforcement for novice drivers to comply with this low risk strategy needs to be explored as well as the influence of parental non-compliance. Blind spot checks are heavily weighted in the RMS practical driving test in NSW. A learner driver must complete the driving test with 2 or less blind spot check errors. The third error constitutes a fail item. Learner drivers are motivated to perform these checks to ‘pass the test’: there is little motivation to comply with this after the driving test. Blind spot checks or observation checks are performed to observe the area where the side mirrors do not cover.

Indicator usage on roundabouts has recently been the subject of an advertising campaign in NSW to increase compliance. The participants were asked, “Do you put your left indicator on when exiting a roundabout?” 51% of participants answered ‘Yes’ they did indicate off a roundabout where 29% answered sometimes and 15 % never. Of those participants that answered never the main reasons given were “didn’t know they had to” and “it is confusing”.

Speeding is the major cause of death and injuries in accidents for novice drivers in the 16 – 25 year old age range. 28 % of participants answered ‘Yes’ to driving over the speed limit with 50 % of these responses listing they did this regularly. Participants that answered ‘Yes’ to speeding, 70% stated they felt more at risk when they did speed in a motor vehicle.

Mobile phone use is prohibited for learner drivers and provisional drivers in NSW, when asked “do you operate a mobile phone while you drive, including hands free or text?” 9.7% of participants answered ‘Yes’. Further questioning revealed 7.4% occasionally, 0.9% frequently and 1.4% always operated a mobile phone while driving.

Participants were asked as a novice driver what are the main hazards you experience whilst driving, and what worries you the most? (Table 3)

Table 3. Main concerns of young novice drivers

Main hazard/ worry: common response	No. of participants
Other drivers	78
Road and traffic conditions	38
Animals	31
Inexperience	30
Speeding	28
Pedestrians	23
Fatigue	19
Crashes	16
Other – peer pressure, tailgating, parking a car	29

The main single issue that concerned young drivers was other drivers. They felt the behaviour of other drivers towards learners and provisional drivers was frightening and often did not know how to deal with this aspect of learning to drive. This raised a general question of why do learners have to do comply with rules when other drivers break the law all the time.

Drugs and medical issues:

As the survey was anonymous it was an ideal opportunity to ask participants about drug use, both legal and illegal, prescription and non-prescribed medication. To gain a wider perspective of issues that may increase a young drivers risk on road the survey also asked if they had a range of medical conditions that could impact on road safety if uncontrolled. (Table 4)

Table 4. Drug use and effect on driving within young novice drivers

Drug Name	**Common usage**	**Effect on driving**	**No of participants**
Anti-psychotics			
Rixadone Respiradone	Anti-psychotic Bipolar,Schizophrenia	YES Interacts with alcohol	2
Seroquel Quetiapine fumarate	Anti-psychotic Bipolar,Schizophrenia	YES Avoid alcohol	3
Carbomazapine Sandoz	Anti-convulsing, Bi polar	YES	1
Lithium	Manic depression	YES	2
Ablify Aripiprazole	Anti-depressant, Bipolar	YES	1
Anti-depressant (not listed)	Depression	YES	6
Venlafaxine	Anti-depressant	YES	2
Lovan Fluoxetine	Anti-depressant SSRI	YES	5
Cymbalta duloxetine hydrochloride	Anti-depressant	YES Interacts with MAOI drugs and alcohol	1
Zoloft / Sertraline	Anti-depressant SSRI	Yes can interact with alcohol	1
Pristiq Desvenlafaxine succinate	Anti-depressant SNRI	Yes	1
Cipramil Citalopram hydrobromide	Anti-depressant SSRI	YES Avoid alcohol	1
Escitalopram Escitalopram oxalate	Anti-depressant OCD, Anxiety SSRI	YES	5
Seretide	Asthma	NO	4

Asmol	Asthma	NO	1
Ventolin	Asthma	NO	6
Flixotide	Asthma	NO	1
Epilim/xyprexol	Epilepsy	YES	1
Lamotrigine	Epilepsy	YES Avoid alcohol	4
Ritalin Methylphenidate hydrochloride	ADHD Narcolepsy	YES Negative interaction with alcohol	3
Concerta Methylphenidate hydrochloride	ADHD	YES	2
Insulin	Diabetes	YES if not controlled	1
Metaformin	Diabetes	NO	1
Ixprim Opioid, Tramadol	Pain killer	YES	1
Celebrex Celecoxib	Arthritis/menstrual cramps	Possible side effects	1
Hypothyroid drugs		UNKNOWN	1
Roaccutane Isotretinoin	Acne	NO	2
Doxycycline	Antibiotic	NO	2
Unknown drug		UNKNOWN	3
Crystal meth		Yes	1
Marijuana		Yes	1

Young drivers and parents need to be aware and educated on the affect certain drugs have on driving ability to help reduce the impact on road safety. Some of the medical conditions outlined have the potential to delay a young driver’s ability to gain a provisional drivers licence such as epilepsy where a mandatory non drive period is enforced until symptoms have settled. With the additional factor of peer influence in this age group there is a potential for young drivers to ignore exclusion periods or not report the medication or condition to the RMS increasing their risk factor on the road.

Drummer argues that ‘the role of prescribed medication in road trauma is uncertain. In general, most drugs tend not to be significant risk factors on the road when the drugs are used as prescribed.’(Drummer, 2008)

It is however a risk factor when medication is not taken as prescribed, particularly in the earlier stages of treatment such as depression. Many medications impair necessary skills required to operate heavy machinery with specific effect on attention, concentration, visual acuity, coordination and reaction times. Drugs in general, other than alcohol, have been implicated in approximately 30% of Australian driver fatalities (Gowing, Holmwood & Edmonds 2005).

Road safety advertisement:

Participants were asked to describe the most memorable road safety advertisement and if they felt it improved their behaviour when driving. There was a high nil return rate on this question which could be attributed to advertising not connecting with this target audience. The following are the most popular three responses for advertisement recall in this age group.

- Dr Owler multiple choice advertisement – Take the slow down pledge
- RBT Plan B – What's your Plan B
- Speeding – No one thinks big of you: Roads Traffic Authority (RTA NSW)

Although many answers listed in the surveys could not name the specific advertisement they did describe them accurately, Plan B was the most recognised by name and therefore held more recall potential to this audience group.

Overall findings:

The survey was a necessary first step in benchmarking the issues young novice drivers faced in the regional areas of NSW. For many years the program has relied on road safety information, research and local knowledge to convey an important underlying principle of attitude and behaviour change to tackle road trauma. These are all necessary components to ensuring an effective education program. However, one area that had been omitted was the young driver's perspective of what issues they faced as novice drivers and their active involvement was needed (Faulks et al. 2008). The survey allowed this road user group to voice the areas that concerned them in relation to road safety. For a solution to be effective in reducing road trauma in this vulnerable road user group it is essential that all key stakeholders contribute to the solution. A collaborative approach that was inclusive of young drivers needs was necessary to begin the process of ownership of the issues and being instrumental in allowing the young drivers to help solve the problem.

The data highlighted a need for changes to the current curriculum of the *U Turn the Wheel* road safety program to ensure key information is given to this road user group to help prevent and reduce road trauma. The information gained also allowed key stakeholders the opportunity to review the skill and knowledge gaps within this road user group. By a coordinated approach road safety governing bodies such as the RMS, educational groups such as schools, driving instructors, road safety officers, course providers, and more importantly parents/supervisors and learner drivers will increase awareness of the issues faced by this age group and develop effective training to help reduce the negative effects of these risk factors (OECD/ECMT, 2006).

The main areas that were found in this survey for an urgent review within the educational program included:

- *Prescription drug use and effect on driving*: the main drugs used within this group were anti-depressants, anti-psychotics and ADHD medications. All categories affect a driver's ability to operate a vehicle safely if the medication is not controlled. Evidence suggests more education is required for this age group on drug use/ interaction and driving, as well as RMS exclusion requirements and AUSFIT compliance.
- *Demerit point system and how it works:* young drivers had little knowledge of the demerit system or how it operates. For the young driver to be aware of negative consequences when driving it is important they are familiar with the scheme to encourage compliance.
- *Further support for medical and learning issues in relation to learner drivers*: as the incidence of autism spectrum disorders and learning disabilities increases a

coordinated structured approach to supporting these young drivers is necessary to decrease their risk factors on road.

- *Choices we make when driving – low risk driving strategies and why they are used*: there was limited knowledge on current low risk strategies that can be employed whilst driving and how these can decrease a driver's risk. There was also a general feeling amongst participants that compliance to these strategies was only necessary to pass the test. Reinforcement through parents and supervisor's needs to be explored further. The main aim of driver education is to produce safer drivers, defined in terms of accident involvement not how to pass a driving test (OECD/ECMT, 2006). This paradigm change is a necessary one for all key stakeholders involved in road safety if real change is to be made.

The survey results are currently being used to review the content of the *U Turn the Wheel* program and this will form the basis of an educational review. The *U Turn the Wheel* committee has already implemented one recommendation by Redshaw (2005) and has included a plenary session open for discussion and to ensure all sessions have been linked together with a unifying message (Faulks et al, 2008).

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Maximising positive driver behaviour change and minimising driver distraction in the deployment of Cooperative Intelligent Transport Systems

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Abstract

Cooperative Intelligent Transport Systems (CITS) are emerging technology solutions with huge potential to improve road safety. CITS use Dedicated Short Range Communications to send and receive data between vehicles and infrastructure. The Cooperative Intelligent Transport Initiative is the establishment of an integrated testbed in the Illawarra region of New South Wales to facilitate the testing, measuring and assessing of CITS. Up to 60 heavy vehicles and a range of roadside infrastructure have been fitted with CITS. Participating drivers receive visual and auditory messages on an in-vehicle display. Messages include collision avoidance warning between equipped vehicles and alerts when exceeding the heavy vehicle speed limit or approaching red traffic signals.

A key focus in planning the testbed has been to maximise positive changes to driver behaviour while minimising the potential for the technology to distract from the driving task. To do this, the proposed warnings and information messages were assessed for clarity, consistency, and impact on driver workload against Human Machine Interface (HMI) design guidelines prepared for this project. The HMI design was subsequently revised based on this assessment. Other mechanisms to minimise driver distraction included a comprehensive driver induction package and customisation of the placement of the in-vehicle display screens for different cabins.

This paper will discuss the CITS initiative and the process used to optimise the HMI. By considering the impacts on driver behaviour and driver distraction now, road safety practitioners will be well-placed in the future to oversee the deployment of CITS in a manner that maximises its potential benefits.

Introduction

Cooperative Intelligent Transport Systems (CITS) use Dedicated Short Range Communications (DSRC) to transmit information between vehicles and between vehicles and infrastructure. This information can lead to important, concise messages being given to drivers - for example, to alert drivers of a potential collision or weather or congestion alerts. CITS increases the quality and reliability of information available to drivers about their immediate environment, other vehicles and road users by providing information that may not be directly visible. Some anticipated benefits include improved road safety, increased network capacity, reduced congestion and lower vehicle operating costs.

Researchers in the United States estimate that CITS has the potential to positively impact on 80% of crashes involving an unimpaired driver (Harding et. al. 2014). In the United States policy makers have announced an intention to implement a regulation that will require the technology to be installed on all new light vehicles. (National Highway Traffic Safety Administration, 2014). Research and testing of CITS in an Australian environment will allow researchers to examine some of the potential local impacts and learn more about the deployment of CITS.

Transport for NSW has established Australia's first CITS testbed in the Illawarra region of NSW, known as the Cooperative Intelligent Transport Initiative (CITI). The testbed provides an environment that allows testing, research and development of CITS in an Australian environment. This is the world's first CITS testbed dedicated to heavy vehicles. The testbed includes:

- 60 heavy vehicles equipped with CITS, including in-vehicle display of safety alerts
- 3 traffic signals equipped with CITS, broadcasting signal phase information to equipped vehicles
- 1 portable roadside unit broadcasting speed limit information to equipped vehicles
- 2 portable roadside units receiving and collecting data from equipped vehicles.

The CITS technology installed in the 60 heavy vehicles allows them to communicate with other equipped vehicles and with CITS-equipped infrastructure. Each heavy vehicle is fitted with a DSRC Radio and DSRC antennas, GPS and a 7-inch in-vehicle audiovisual display. In the first phase of the testbed, drivers will receive the following messages: forward collision warning, intersection collision warning, heavy braking ahead alert, red signal phase alert and truck speed limit information. Over time, more alerts will be added.

Method

Prior to proceeding with the installation of 60 CITI devices in heavy vehicles, Transport for NSW commissioned the Monash University Accident Research Centre (MUARC) to undertake a project to understand the potential impacts on driver behaviour and safety of providing visual and auditory warnings on an in-vehicle display.

First, a targeted review was conducted of previous research that has examined the safety impacts of in-vehicle driver assistance and warning systems that are similar in nature to the CITI device. Second, a set of Human Machine Interface (HMI) design guidelines were developed to minimise the unintended negative effects on driver behaviour of the CITI device. Finally, an assessment of the proposed CITI messages against the HMI design guidelines was conducted and changes were made to the HMI based on this assessment.

Other mechanisms to maximise driver safety included a comprehensive driver induction package and customisation of the placement of the in-vehicle display screens for different cabins.

HMI Design Guidelines

The review of the literature (Young & Lenné, 2013a) identified four main ways in which the use of in-vehicle warning systems may negatively impact on driver behaviour and safety. These are:

1) drivers adopting risky driving styles and behaviour

   What motivates drivers to engage in riskier behaviours when driving with in-vehicle warning systems is not clear, but may be because drivers are seeking to maintain a preferred target level of risk (Peltzman, 1975; Wilde, 1994) or because drivers are trying to improve their mobility or compensate for factors such as lost time due to the lower speeds brought about by some support systems.

2) over-reliance on the system

3) increased or decreased driver workload

   The introduction of in-vehicle warning systems can reduce the attentional demands on the driver as the system takes over a proportion of the workload (e.g. monitoring of following distance). This reduction can result in driver underload (Young & Stanton, 2007). When a driver's mental workload is reduced enough it can lead to a reduction in situation awareness or boredom. This may lead to an inability to cope with a sudden increase in task demand, as can occur during a system failure or a safety-critical event that the system is not designed to handle (Ward, 2000; Young & Stanton, 2007).

4) driver distraction.

Many of the negative safety impacts of in-vehicle warning systems identified in the review can be overcome with good HMI design or appropriate training. HMI design guidelines for in-vehicle warning systems were developed. These aimed to ensure the CITI device met best practice design principles and that the use of the CITI device while driving led to minimal distraction and changes in workload. The focus of the guidelines was on the visual and auditory presentation of warnings and information to drivers. The guidelines comprise five sections: general design principles; visual display; auditory display; multiple warning design and scheduling; and portable device placement. The guidelines primarily consist of high-level, principle based guidance that is applicable to a range of visual and auditory driver warning systems.

There is the potential in the future for the vehicle to respond automatically rather than issue a warning to the driver. For example, by automatically applying the brakes when the CITS technology determines that a collision is imminent. This has not been explored in the CITI project at this stage. As the technology for automated vehicles matures, the need to provide warnings so that drivers can respond will lessen, and the vehicle's systems will automatically take action. It is expected that this will reduce negative impacts on driver behaviour from in-vehicle warning systems.

Assessment of the CITI Device HMI

The guidelines were used to determine if the initial design of the CITI device as customised by Transport for NSW met best practice design principles in relation to usability and safety (Young & Lenné, 2013b). For each alert, an assessment was made as to whether it conformed to each relevant HMI guideline. Overall, many of the alerts individually conformed to the HMI guidelines. Some changes were made to the image, auditory tone or spoken message of some alerts, to distinguish different alerts from each other and to aid fast recognition of the meaning of each warning.

Driver Training

The literature review which was conducted to assess the safety impacts of in-vehicle warning systems found that issues such as system overreliance and some risky driving behaviours such as experimenting with the system can be overcome with training. The training must inform drivers how the system operates and what it is capable of doing and not doing and of what aspects of the driving task drivers will still need to be in control.

Transport for NSW prepared and delivered a comprehensive training package to induct drivers and familiarise them with the system. The training included a presentation that gave an introduction to CITI, the equipment being installed in vehicles and expectations of drivers. Most importantly, drivers were shown each message that the CITI device may generate. Animations were produced that effectively depict each scenario where an alert may be triggered, show what the alert looks and sounds like, and described what action a driver may need to take. The training package also included a fact sheet and user guide.

Placement of in-vehicle display

A 7-inch tablet was installed into each heavy vehicle and placement of the display was carefully considered. The size, shape and layout of each heavy vehicle's interior cabin, dashboard and windscreen differed greatly from vehicle to vehicle depending on the make and model. In addition to the constraints of the interior, many vehicles had existing equipment including dispatch systems, communication radios, and other devices. For each installation the drivers, fleet manager and installers were consulted as to where the best position may be. The placement of the screen in each vehicle was customised to suit the vehicle and the drivers of that vehicle. Improved safety and increased driver acceptance was achieved by consulting with the relevant stakeholders to identify their requirements and any usability issues. The HMI guidelines were also taken into consideration so that the CITI device was mounted securely to the vehicle, did not obstruct the driver's forward field of view or access to vehicle's controls and was placed as close as practicable to the driver's normal line of sight.

Conclusion

The Cooperative Intelligent Transport Initiative is establishing Australia's first CITS testbed to further explore the benefits of CITS and learn about the deployment of this technology. 60 heavy vehicles are being fitted with CITS and receive safety messages through an in-vehicle display. A review of the literature shows that in-vehicle warning systems can have both positive and negative effects on driving behaviour. In order to maximise positive driver behaviour changes and minimise any negative impacts, HMI design guidelines for in-vehicle warnings were developed based on best practice. The HMI of the CITI device was assessed against these guidelines and changes were made to the visual and auditory message of some alerts. Appropriate HMI design will become more critical in the future, as more CITS are introduced into new vehicles. The HMI design guidelines developed for CITI can be applied to all in-vehicle warning systems to assist in maximising the potential positive road safety benefits of this new technology.

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Onslow Road Users Group (ORUG) Taking Action Together - Making a Difference

Jaydon Vernes

Chairperson, Onslow Road Users Group

Background

Onslow is a coastal town in the Pilbara region of Western Australia, 1,386 kms north of Perth and has a population of less than 700 people.

In recent years, the businesses of producing salt and refining gas have made a large impact on the community, in particular the use of the road network. As a result, it has a fly in – fly out (FIFO) population of up to 5,000 with an increase of up to 1,500 vehicles

With an increase in light and heavy vehicle activity in the Onslow region due to industry, it was imperative that effective strategies needed to be implemented to reduce the risk profile for all road users within the area.

The Onslow Road Users Group (ORUG) was formed in 2013 and is a perfect example of “Taking Action Together”.

ORUG has brought together the knowledge and resources of local stakeholders with the common goal of reducing road related trauma and delivering positive road safety outcomes to the Onslow region.

This Group is not a financial group and where required, obtaining funds through specific application for projects. The ongoing work of the Group relies upon the members taking action together for the purpose of road safety.

ORUG are an advocate on behalf of the community by providing an avenue for community members to get road safety messaging to the right people. We focus on identifying and resolving local hazards with a consultative approach. We actively promote and educate to make a difference.

The Group

Our vision is to share in the responsibility of delivering road safety within the Onslow Region and communities impacted by industry.

In taking action together, the ORUG combines the following stakeholders:

Shire of Ashburton	**WA Police**
Drilline	**St John Ambulance**
Local education representatives	**Main Roads Western Australia**
Onslow Salt	**Western Australian Local Government Association (WALGA) Roadwise Program**
Chevron Wheatstone	**Chevron Public Affairs**
McMahon Burnett	**NTC Trucking**
Ertech	

The Onslow Road Users Group has adopted a Terms of Reference to provide scope and context to the activities and work of the Group. The Terms of Reference include the following principles:

- Collectively meet on an agreed basis to discuss road safety issues associated with the members activities in the region and implement road safety initiatives.
- Have full representation at all meetings.
- Actively implement and report on road safety and road safety initiatives undertaken within the organisation's workplace and greater Onslow area.
- Individual organisations will be responsible for executing their own actions taken from the group.

To achieve this, our objectives are:

- To drive a coordinated and proactive approach to road safety
- To identify and address road safety hazards
- To participate in safety improvement on road networks that Onslow Road Users Group has influence over.
- To improve road safety and reduce road trauma by working together to educate workforces and communities in the Onslow Region.

Successes

Initiatives for ORUG have included working with the Onslow School to implement road safety education programs such as working with local Police around enforcement strategies.

Involvement of members has also assisted with local traffic management issues through identification of high risk areas and working with relevant stakeholders to reduce the risks.

The Group has embarked upon enticing other community education campaigns for Aboriginal driver training in the area and is working with the Native Title Owners to initiate the contact as required by the training provider (Red Dirt Driving Academy).

The Group has also devised some strategies that are already in place to limit heavy vehicles and Industry traffic in town, these will continue and evolve. This has been achieved through relationships with industry representatives who have created internal directions to staff and contractors.

One company having the largest impact to the community for road use, has seen the benefit of the Group in terms of Road Risk Management and have implemented a combined 90 day forecast of heavy haulage movements in the area for all their scopes. This forecast is delivered to members of the Group on a regular basis and allows ORUG members to assess and identify any conflicts with the movements. This company can then address this and reduce the risk by altering schedules where necessary.

Other achievements

ORUG has built a foundation on attending to a variety of road safety matters.

Community Concerns:

- ✓ Coordinating action and education on cyclists riding down Second Ave (the main street in Onslow) with no helmets and lights
- ✓ Attention to speed of vehicles near the post office and along Second Ave being effectively addressed with Police action based on MainRoadsWA data from speed strips
- ✓ Connecting the school Principal with the correct stakeholders involved in the Ring road design and location for local school input
- ✓ Dealing with reverse alarm issues within the town
- ✓ Quick resolution of community complaints about loose rocks along Onslow Road (only road into town)
- ✓ Reducing excessive use of local side streets by industry trucks and light vehicles

Promotion:

- ✓ Designing an ORUG Logo
- ✓ Development of the ORUG Facebook page to connect to the community
- ✓ ORUG badged vests for members to be easily identified

Raising Awareness:

- ✓ Utilising the crash display trailer from Karratha in Town and on Industry sites
- ✓ Active participation in the Passion of the Pilbara event with an ORUG road safety stall promoting road safety messaging and advertising the work of the Group in the Town
- ✓ Road safety messaged key rings and stickers

Education:

- ✓ Successful funding of driver education tools i.e. Fatal Vision Goggles and standard drink education packages
- ✓ Child restraint checking station and education
- ✓ Connecting the Red Dirt Driving Academy with the Local Thalanyji.
- ✓ Successful funding from a Chevron Community Spirit Grant for conducting a road safety event in Onslow. Working together with the Pilbara Regional Council this incorporated:
  - ✓ Trucking safety messaging to school students
  - ✓ Motorcycling WA education speech to school students
  - ✓ Two locals to be trained in Child Car Restraint checking and installing

Results

Onslow community knowledge of the ORUG is strong. Working together it is clear that road safety messaging has made an impact in the community. More children are wearing helmets and more passengers are wearing seat belts. With more time and funding, the ORUG have a desire to formally evaluate the Group's effectiveness.

Challenges

Onslow is an isolated community and there is substantial cost for travel and deliveries of items. Funding to the Group is necessary to continue with our ongoing road safety campaigning. Not all members live within Onslow but have a passion to work together to achieve a successful outcome.

Our future

At a recent ORUG meeting, a local business owner raised a local concern with the issue of children riding motorcycles and bicycles around town without the proper safety equipment. The local business owner is also from the Thalanyji Native Title Owners and has asked for a specific education project to target Aboriginal youth and their parents for riding safely.

To continue taking action together and making a difference, ORUG have decided to take on an initiative to tackle the opportunity, which includes:

- Providing helmets and encouraging the use of these
- Developing and implementing an education package for both children and parents
- Linking other social/community initiative/opportunities

Project grant funding application has now been submitted to the WA State Government Road Safety Community Grants Program to implement this initiative.

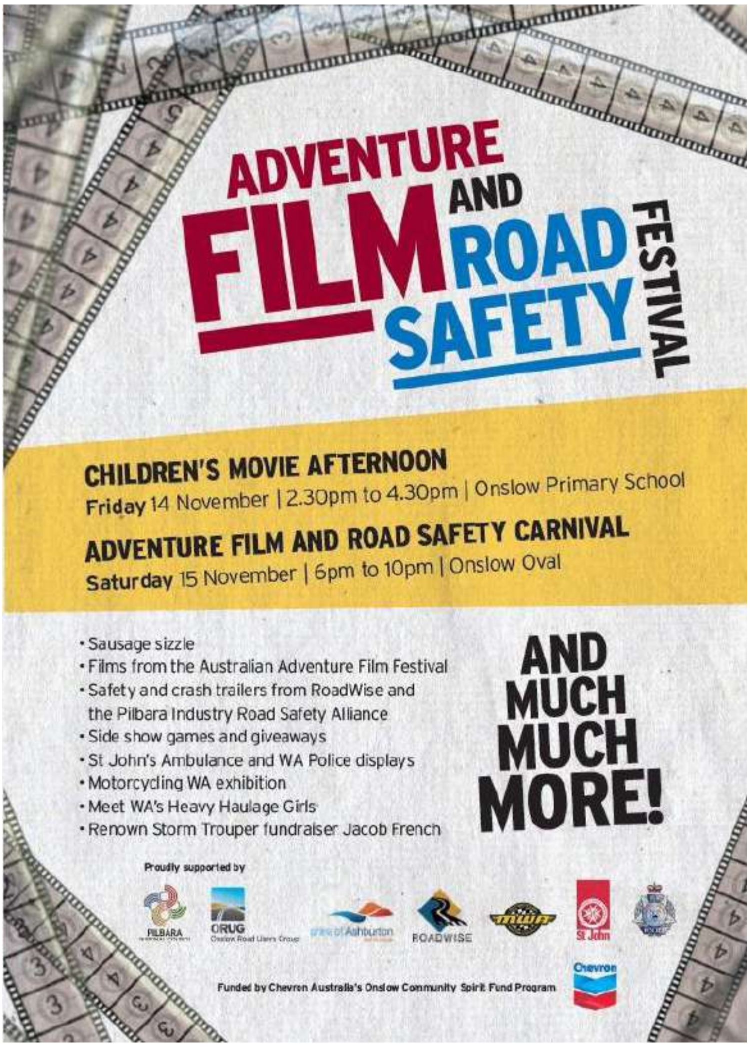
Although the ORUG was only established just over two years ago, the members have succeeded in providing a focal point for the Onslow community to have their road safety issues raised and addressed by the appropriate stakeholders. The ORUG Facebook page provides an easily accessed avenue to deliver a source of road safety messages to the broad Onslow community and to showcase the Groups many achievements.

Onslow residents have come to accept the ORUG as their own and are pleased to have a local group acting on their behalf for road safety issues.


ORUG


ORUG


SLOW DOWN
SPEED KILLS


ADVENTURE
FILM AND ROAD SAFETY
FESTIVAL
CHILDREN'S MOVIE AFTERNOON
Friday 14 November | 2.30pm to 4.30pm | Onslow Primary School
ADVENTURE FILM AND ROAD SAFETY CARNIVAL
Saturday 15 November | 6pm to 10pm | Onslow Oval
• Sausage sizzle
• Films from the Australian Adventure Film Festival
• Safety and crash trailers from RoadWise and the Pilbara Industry Road Safety Alliance
• Side show games and giveaways
• St John's Ambulance and WA Police displays
• Motorcycling WA exhibition
• Meet WA's Heavy Haulage Girls
• Renown Storm Trouper fundraiser Jacob French
AND MUCH MUCH MORE!
Proudly supported by
PILBARA
ORUG
ROADWISE
St John
Chevron
Funded by Chevron Australia's Onslow Community Spirit Fund Program


SCANIA
TOWARDS ZERO
Police
ORUG


Tips to share the road safely
Look out for each other
SHARE OUR ROADS


POLICE

Laser Ablated Removable Car Seat Covers for Reliable Deployment of Side-torso Airbags

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Abstract

In the event of a collision, the safe and reliable deployment of side-torso airbags through removable car seat covers that use tear-seam technology has been recently questioned. It is well known that a side-torso airbag system in automotive seats can reduce injuries and prevent fatalities in the event of a collision. Removable car seat covers suitable for side-torso airbag systems are popular accessories in the automotive industry from the perspective of upholstery protection and aesthetics. This study demonstrated a better-suited technology in which laser ablation down the side panel of removable car seat covers, produced a pre-determined strength within a weakened zone that allowed a reliable airbag deployment in the event of a collision. This paper investigates the effect of laser power as a key factor in the laser ablation process and its influence on the bursting strength of the car seat cover materials. The laser-ablation of the removable car seat covers can ensure the consistent airbag deployment under environmental conditions ranging between as ambient (22 ± 2°C), cold (-35 ± 2°C) and hot (85 ± 2°C). The durability and deployment performance of these car seat covers after UV exposure were also investigated.

Keywords

Laser ablation, textiles, car seat covers, side-torso airbags, bursting strength

Introduction

Airbags in passenger vehicles are a supplementary restraint system to seat belts that further mitigates the injuries suffered in serious crashes. The use of airbags can help to minimise the chances of fatalities from an external collision, and limit passenger impact with the inside of the car. Airbags were first introduced in passenger cars by Ford in 1971 to protect the driver and front passenger in frontal collisions. Since then, the number of airbags in modern cars has increased to 5 and in some cases to 9, covering a wide range of accident scenarios. Side airbags were first introduced into vehicles around 1995 to help protect passenger car occupants from serious injury in struck side crashes. International studies have shown that side airbags are effective in reducing the risk of death in near side impact situations, and mitigate injuries in vehicle rollovers (Braver & Kyrychenko, 2004). A driver involved in a side impact has twice as high fatality risk as driver involved in frontal impacts (Farmer, Braver, & Mitter, 1997). In 2014 in Australia, 1299 passenger vehicles were involved in police-reported fatal crashes. These crashes resulted in 763 deaths (BITRE, 2014).

Airbags in front occupant car seats are generally concealed in a moulded plastic enclosure contained within the side upholstery of the seat as either a head-and-torso or torso-only system. The seat upholstery through which the side airbag would deploy involves a tear-seam technology that facilitates the inflation of the airbag during a collision. For a moving vehicle, airbags primarily deploy for crashes at speeds greater than 30 km/h (Toyota, 2015). When an internal accelerometer senses a possible collision, a microprocessor senses the vehicle deceleration and other relevant parameters and initiates the deployment of the airbag (Huffman, 2011). At the time of deployment, the airbags release by rupturing the moulded plastic enclosure within the seat, followed by bursting of the tear-seam of the upholstery of the fitted seat. The airbag deployment is executed with an enormous velocity of 200 – 320 km/hr (Braver & Kyrychenko, 2004; Farmer et al., 1997)

The use of removable car seat covers over the standard upholstery is a popular accessory used to protect the upholstery as well as to give aesthetic appeal. Similar to the car seats, the removable seat covers also include a tear seam along the side gusset to enable the deployment of the airbag during a collision. It is imperative that the seat cover never obstructs the full deployment of the airbag.

Our research has identified that current seat cover designs that employ tear-seam technology have issues of reliability and predictability during airbag deployment, due to various technical and design deficiencies in the tear-seams. Several factors such as fabric stretch, the strength of sewing thread used at the tear-seam, the length of the tear-seam, the placement of the tear-seam, the type of stitch, and stitch density can affect the behaviour of airbag deployment. As a consequence, ballooning of the seat cover material prior to the failure of the seam can occur which increases the time taken for the airbag to deploy, thus reducing its effectiveness.

Laser processing in the automotive industry for applications such as cutting, drilling, marking, welding and the surface treatment of materials such as ceramics, and plastics is well established (Roessler, 1989). In the textile industry, laser processing has been used extensively for cutting of fabrics (Jackson, Preston, & Tao, 1995); engraving designs on fabrics (Yuan, Jiang, Newton, Fan, & Au, 2011) and carpets, surface modification of fabrics (Chow, Fibers and Polymers 2011), decorative finishes on denim (Ortiz-Morales, Poterasu, Acosta-Ortiz, Compean, & Hernandez-Alvarado, 2003), and wool felting (Nourbakhsh, Ebrahimi, & Valipour, 2011). The lasers technologies used in these industries usually employ CO_2 and neodymium-doped solid-state lasers. In textile manufacturing, CO_2 lasers are predominantly used with typical operating power efficiencies in the range of 5 – 15 % and maximum continuous power outputs well over 10 kW. For comparison, solid-state lasers are characterised by much lower power efficiencies and are operated in a pulse mode. The wavelength of the emission from a CO_2 laser is about 10 μm, whereas the neodymium-doped laser is often characterised by an emission wavelength centred at 1.06 μm, a factor of 10 shorter than that from CO_2 but still in the infrared region.

The use of laser processing to facilitate cutting in a predetermined pattern for strategic weakening of car interior door panels that cover the exit points for airbags has been explored by Riha et al. (2006). Similarly, Bauer (2001) researched the use of a controlled laser beam to weaken the back of the cover layer of trims of a car interior by wholly cutting through the substrate and partially through the cover layer to produce grooves of a precise depth and width. Costin (2000) investigated the application of laser technology to impart patterned designs on thin fabrics and leather by using an electronic controller to direct the drive mechanism for controlling the speed of etching.

The concept of using lasers to pre-weaken the side panel of a removable car seat cover has not been explored until now. Laser processing for such applications required the development and demonstration of pre-weakened fabrics to allow for reliable, predictable and timely deployment of airbags through the tearing of the fabric cover. While many of the above authors have attempted to modify fabric surfaces using laser to allow for deployment, the concept of pre-weakening a precise zone to a known bursting strength has not been demonstrated.

There are several challenges that can be encountered when using the pre-weakening concept on removable car seat covers. Unlike fixed trims and face fabrics that are adhered to the foam of the car seat (as in the case of OEM car seats) removable car seat covers can distort and result in significant misalignment from the actual deployment zone which can create serious performance issues. The objective of this research was to develop a pre-weakened and predetermined zone having a known bursting strength for facilitating reliable side airbag deployment from a car seat.

Experimental

Fabric material

100% polyester weft knitted textile fabrics supplied by Who-Rae Pty Ltd were used for the experimental investigations. The fabric properties are as shown in Table 1.

Table 1 Fabric material specifications

Parameters	**Details**
Yarn used	100 % Polyester
Yarn count	100 denier
Mass per unit area	100 g/m^2
Courses/cm	9
Wales/cm	10

Laser ablation of fabric

Laser ablation of fabric was performed using a commercial CO_2 laser in atmospheric conditions. The generated wavelength of the laser beam was set at 10.6 µm and the laser power was set at 80 - 150 W. The applied laser etching software was LaserCut® and laser engraving on the fabrics involved pattern files designed using Adobe Photoshop® graphics design software. The JPEG files were created in grayscale. The fabrics were placed in an etching cabinet for the laser treatment at different intensities by varying the process parameters.

The controlled laser has three operational parameters that were varied to control the ablation of lines of weakness on the fabric, namely power, the distance between the ablated lines and the angle of the lines. The intensity of the laser was optimised by changing the scale of power incrementally from 1 to 20 %; where the intensity of the ablation increased with higher laser power; and adjusting the distance between the lines.

Performance assessment of the laser ablated fabric material

Bursting strength

The bursting strength of the laser ablated fabrics were evaluated using a SDL Atlas Autoburst® M229 hydraulic bursting strength instrument in accordance with ASTM D3786 standard test method (ASTM, 2001). Ten specimens of each of the experimental fabric samples were tested. The specimen size was 15 cm x 15 cm.

Accelerated UV exposure

A UV exposure test was conducted in accordance with SAE J2412/ J2413 (SAE, 2012). A Ci400 Weather-Ometer was used for this test. Laser ablated fabrics were exposed to 263 kJ/m2 of UV radiation. The UV exposed samples were subsequently tested for bursting strength.

Static airbag deployment testing

Static airbag deployment testing was conducted at a NATA accredited airbag testing facility APV Engineering and Testing Services, Melbourne. The airbag deployment testing was carried out under different environmental conditions which included ambient (22 ± 2° C), cold (- 35 ± 2°C) and hot (85 ± 2°C) temperatures.

Results and discussion

Airbag deployment tests for tear-seam technology based seat covers

Random batch testing of to determine the reliable airbag deployment through seat covers, is a standard industry practices from a quality assurance perspective. Such tests are based on static airbag deployments and are commercially undertaken through an accredited laboratory. Results obtained from 2010 to 2014 are shown in Figure 1, and indicate that over 40% of side torso airbags failed to deploy through the tear-seam car seat covers. Investigation of the these seat cover designs have issues of reliability and predictability, due to various technical and design deficiencies in the tear-seams, such as fabric stretch, strength of sewing thread used in the tear-seam, length and placement of the tear-seam, type of stitch, and stitch density.

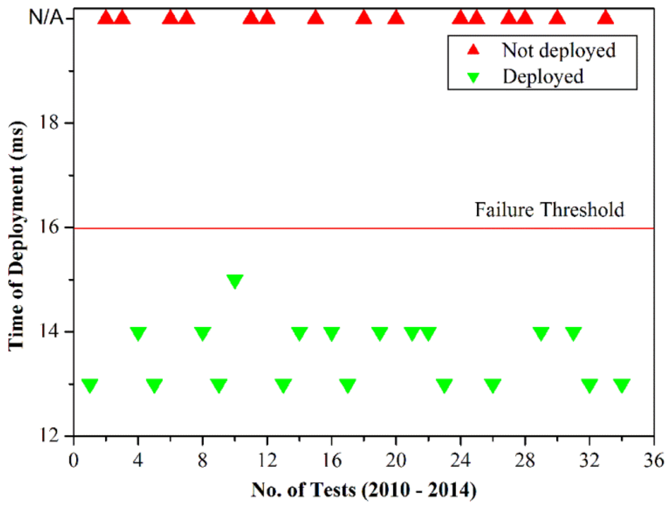

Figure 1 Airbag deployment testing of car seats covers with tear seam technology

Effect of laser power on the bursting strength of fabric

Figure 2 shows the effect of power intensity of the laser on the bursting strength of the ablated polyester fabric. As the power intensity increased from 7% to 13%, the bursting strength of the fabric was decreased.

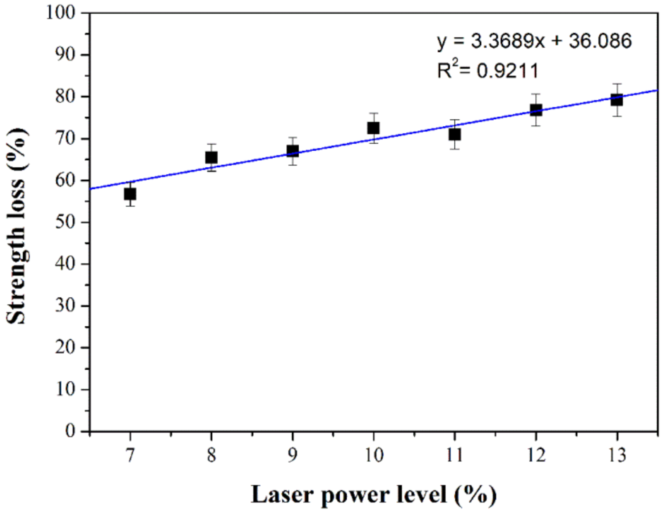

Figure 2 Relationship between laser power and bursting strength

In order to determine the optimal bursting strength of the laser ablated samples acceptable for timely deployment of an airbag, laser ablated fabrics of different power intensities were integrated into the cut-and-sewn car seat covers as side panels. These seat covers were subjected to static airbag deployment testing, initially at standard atmospheric conditions. Figure 3 shows a magnified image of the laser ablated pattern before (a) and after fabric bursting test, and Figure 4 shows the typical airbag testing before and after deployment.

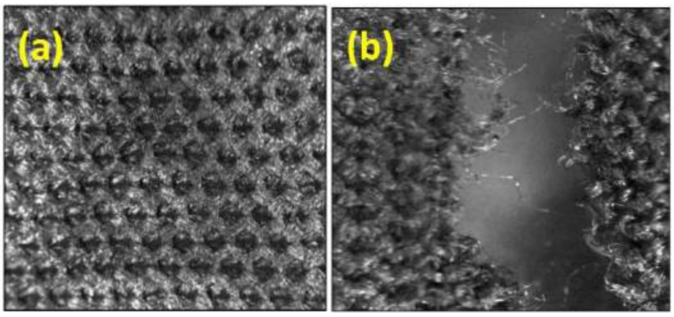

Figure 3 (a) laser ablated weakened area, (b) fabric tear at weakened area

Figure 4 Airbag deployment testing (a) side view before deployment (b) side view after deployment (c) front view before deployment (d) front view after deployment

Effect of bursting strength of laser ablated area on the airbag deployment time

Figure 5 **Error! Reference source not found.**shows the relationship between the bursting strength of the laser ablated area in the pre-weakened zone of the polyester fabric and the airbag deployment time. The average time of deployment for a standard side-torso airbag to extend 50 mm, 150 mm and full extension can estimated to be around 3 ms, 7 ms, and 15 ms respectively (Balavich, Soderborg, Lange, & Pearce, 2011). The industry-accepted failure threshold for side airbag systems is set at 16 ms, during which time an airbag is expected to be fully deployed. To pass the acceptable threshold therefore, the deployment time through the seat upholstery and the additional seat cover must be below this failure threshold to ensure reliable deployment of the airbag.

From Figure 5 it can be observed that the timely airbag deployment can be achieved when the strength of the laser ablated fabrics is reduced by approximately 70% from the original strength of non-ablated fabric. The airbag deployment time however exceeds the failure threshold of 16 ms when the bursting strength reduction is less than 60%. If the reduction in bursting strength is greater than 80% the durability of the fabric is compromised and premature tearing of the side panel may occur. According to Figure 5, if the strength is reduced by 60% from the original, the samples may pass the standard but the fabric may not be sufficiently weakened for a deployment if the temperature in the car exceeds 22 ^{o}C.

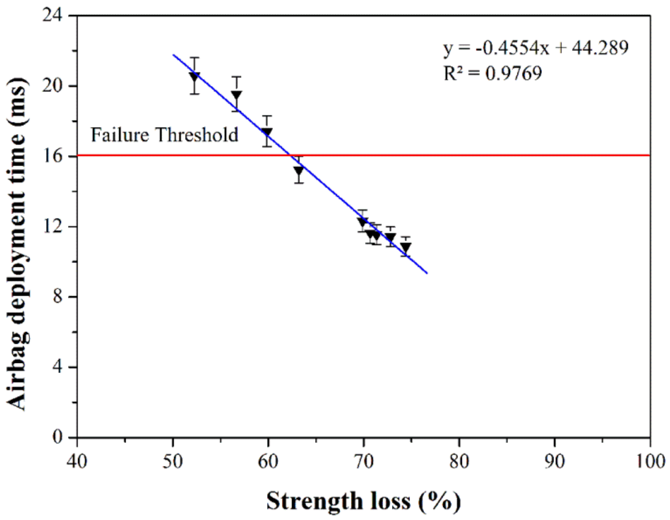

Figure 5 Relationship between bursting strength of laser ablated area and airbag deployment time @ ambient conditions

The laser ablation showed an obvious effect on the bursting strength, when the strength reduced to approximately 25 % of its original.

Effect of environmental condition on airbag deployment time

Car seat covers are used in different geographical locations where the environmental conditions can be extreme. In order to investigate the performance of the car seat covers with the laser ablated pre-weakened side panels, the seat covers were subjected to hot (85 °C), cold (-35 °C) and ambient (22 °C) environmental testing conditions. Figure 6 shows the effect of different environmental conditions on the deployment efficiency and time of the car seat covers having pre-weakened laser ablated side panels. The results showed a slight increase in the deployment time with increase in temperature but were within the failure threshold. This change could be attributed to the change in the fabric elasticity where the stretch of the fabric can be reduced with decrease in temperature.

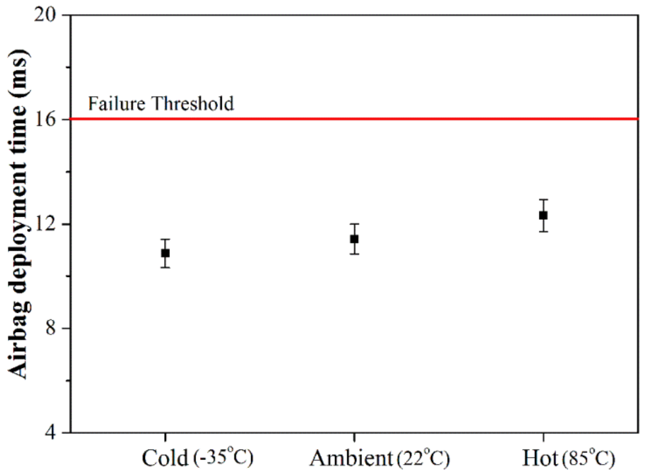

Figure 6 Effect of environmental condition on airbag deployment time of laser ablated car seat cover

Effect of UV exposure on bursting strength of laser ablated area

Based on the requirements of the automotive industry, an assessment of the performance of upholstery and removable car seat covers when exposed to UV radiation must be made to determine the lifetime durability. This parameter was investigated in accordance with the SAE J2412/J2413 standards. Figure 7 shows the effect of UV irradiance on the bursting strength of the laser ablated pre-weakened side panel. The laser ablated fabric panels exposed to UV irradiance intensities of 38 kJ/m^2, 75 kJ/m^2 and 263 kJ/m^2 were tested for bursting strength and static airbag deployment respectively. The fabrics exposed to 263 kJ/m^2 UV radiation showed less than 10% reduction in the bursting strength. This is deemed to be acceptable because the strength of the fabric is expected to degrade over time due to the ageing effects of heat and UV.

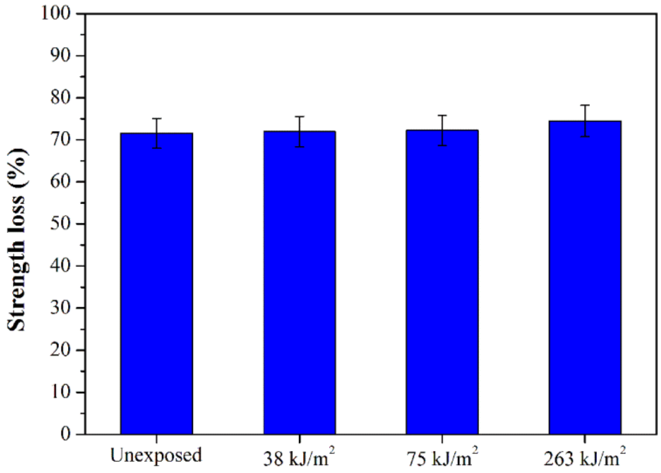

Figure 7 Effect of UV irradiation on the bursting strength of laser ablated area

Conclusions

Laser ablation can be applied in the development of a pre-weakened zone in a car seat cover for reliable deployment of airbags. Laser ablation offers the advantage of being able to adjust the level of weakness of the deployment zone to guarantee 100 % efficiency. Tear-seam technology relies on the quality of the sewing operation and the materials used, and as a consequence this may result in as many as 40 % of tear seams not performing as required. For the chosen fabric, the current research has shown that for timely and efficient deployment, the optimum bursting strength of the laser ablated fabric should be reduced to 25% of its original. This is likely to change for different fabrics and therefore it is recommended that the optimal bursting strength of individual fabrics be determined. The performance of the laser ablated car seat covers tested under various environmental (-35°C, 22°C, and 85°C) conditions, showed an increase in deployment time as a function of increase in temperature, but did not compromise the effective operation of the pre-weakened zone. Laser ablated fabrics exposed to UV irradiance of 263 kJ/m2 showed a reduction of less than 10 % in bursting strength which means its life-time should only be marginally compromised.

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Development of the Australian Graduated Licensing Scheme Policy Framework: a demonstration of jurisdictions taking action together to reduce road trauma

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Abstract

One of the most effective measures to reduce crashes amongst young drivers is the implementation of a comprehensive Graduated Licensing Scheme (GLS). Yet while all Australian jurisdictions have some form of GLS in place, young drivers remain over-represented in crashes on Australian roads. This indicates that improvements to GLS models in each jurisdiction would be beneficial.

The Centre for Road Safety in Transport for New South Wales, on behalf of the Austroads Road Safety Taskforce, commissioned road safety consultants Eric Howard and Anne Harris to develop an evidence-informed GLS policy framework that can be applied across all Australian jurisdictions. The project involved a review of current Australian GLS arrangements, a discussion paper outlining key research findings and extensive consultation with road safety and licensing representatives from all jurisdictions.

The framework identifies fundamental GLS components to guide, rather than prescribe, the implementation of increasingly effective GLS models across Australia. The GLS components relate to key areas of focus that contribute to young driver crashes including age, experience, risk taking and licensing access and support. The framework outlines the features of progressively more comprehensive GLS models that address these issues (i.e. standard, enhanced and exemplar models) to account for the varied starting points across Australia and enable jurisdictions to make improvements gradually.

The Australian GLS Policy Framework was approved by the Transport Ministers of every jurisdiction. The success of this project demonstrates how policy agencies can take action together to reduce Australian road trauma, even when jurisdictions' current policies differ considerably.

Introduction

During the five year period 2008-2012, over 1,600 young Australians (15 to 24 years) died on our roads (BITRE, 2014). One of the most effective road safety measures to address youth road trauma is the implementation of comprehensive, evidence-based graduated licensing schemes (GLS). These are designed to reduce the extent of crash involvement among young drivers by providing a staged approach to driver licensing, minimising the impact of certain risky behaviours associated with young drivers.

All Australian jurisdictions have some form of GLS currently in place. Some jurisdictions have been able to introduce very comprehensive schemes over the last decade. These have been effective with evaluations in two states showing significant reductions in casualty and fatality crashes among young drivers as a result. National road trauma data shows that fatalities among the 15-24 age group have reduced by 29% over the last ten years and each Australian jurisdiction has achieved reductions, largely due to the introduction of GLS models in all jurisdictions.

Despite the reduction in fatalities, young drivers remain the most over represented group of drivers involved in crashes on our roads. Research has shown that young drivers have higher crash risks mainly due to (VicRoads, 2005; Waller, 2003):

- the nature of adolescent development which effects a young person's cognitive and perceptual skills,
- lack of driving experience,
- poor ability to anticipate, perceive, identify and, therefore, react to hazards,
- failure to recognise and assess risk as well as a propensity to take intentional risks, and
- propensity to be over-confident and over-estimate their driving ability.

Improvements to GLS models in each jurisdiction could be implemented to overcome these key reasons why young drivers are over-represented in road trauma.

Development of a GLS policy framework

To help improve GLS models, Transport for New South Wales, on behalf of the Austroads Road Safety Taskforce, commissioned road safety consultants Eric Howard and Anne Harris to develop an evidence-informed Australian GLS policy framework that can be applied in Australian jurisdictions.

The project firstly involved a review of current Australian young driver licensing arrangements, and development of a discussion paper outlining research and evaluation findings. This paper was then circulated to all Australian jurisdictions and meetings were held with road safety policy staff, and where possible, licensing staff and police from all jurisdictions. All expressed interest in knowing what other jurisdictions were doing and in evaluations of new measures. Overall the jurisdictions saw value in the development of a GLS policy framework, as it has the potential to assist them in their work to continuously improve their novice driver licensing systems. Following consultation and input from representatives of all jurisdictions, a GLS policy framework was developed.

It should be noted that the elements of good GLS policy are present to varying degrees in the GLS currently operating in all jurisdictions. The opportunity exists to improve novice driver safety by strengthening existing arrangements and introducing some new measures rather than completely replacing existing approaches.

Framework for improving GLS models in Australia

Based on the available research and GLS evaluations, and taking into consideration the feedback from each jurisdiction, the key elements of an effective GLS were identified. These include:

- licensing age, whereby the older a young person is when they are licensed the safer they are
- having high levels of supervised driving experience in a range of conditions prior to driving solo
- effective testing procedures that can discriminate between more and less safe applicants to only licence those demonstrating safe behaviours and abilities

- risk reduction measures to try to limit the negative impact of the increased risks to newly licensed drivers that are associated with alcohol, distraction, late night driving and driving with multiple peer aged passengers

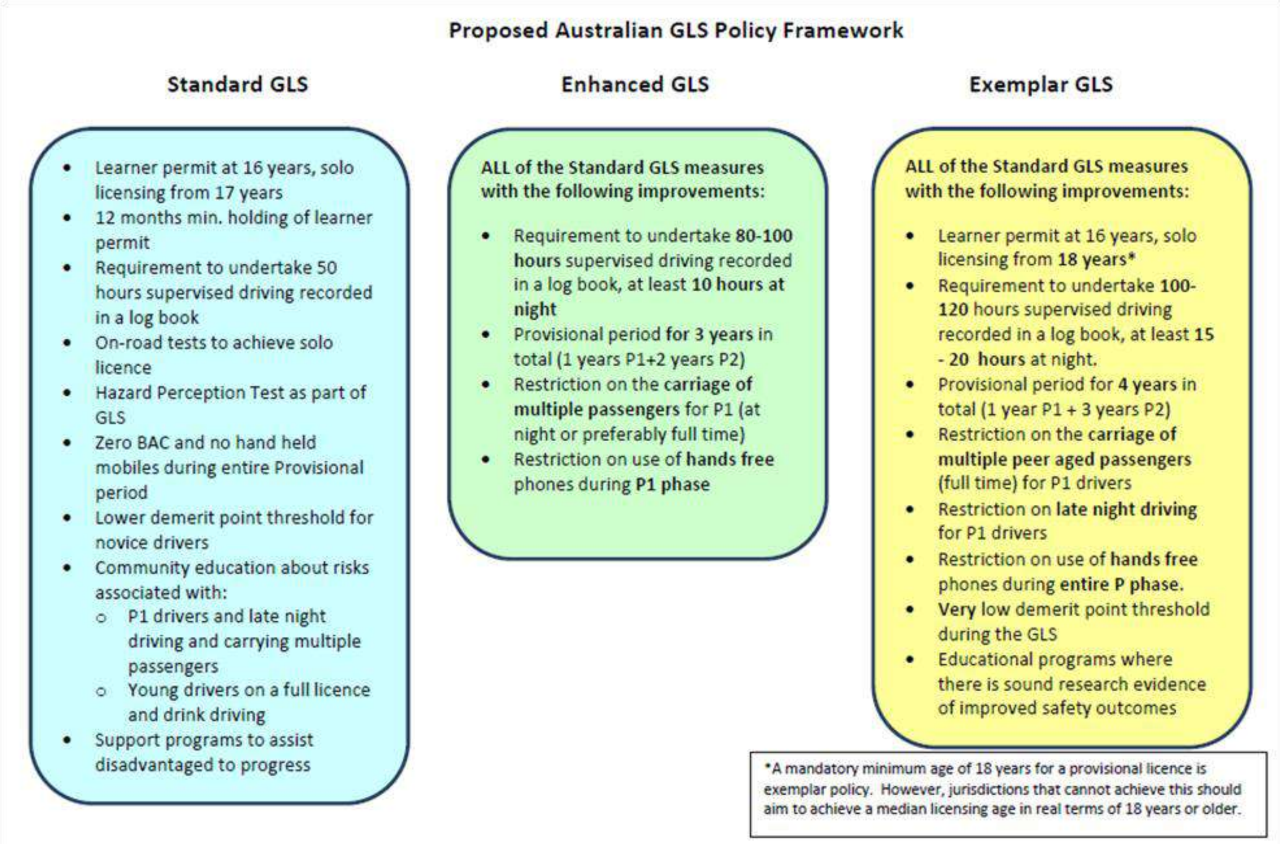
- behaviour control measures, that aim to deter provisional drivers from illegal and high risk behaviours (in particular speeding) by having lower tolerances and more penalties for those that commit offences

- licensing access support measures to ensure that all members of the community can safely become licensed

Each of these elements is discussed more in the next section. These elements have informed the development of a recommended GLS policy framework. This policy framework is designed to be a flexible model that can be used as a "best practice" guide for jurisdictions to implement increasingly effective GLS approaches in Australia. It is not designed to be prescriptive. The framework is a three-staged model – standard, enhanced and exemplar – to account for the varied starting points across Australia and enable jurisdictions to make improvements incrementally.

A key benefit of the three-staged model is that jurisdictions can apply a model that is in line with their current practices and help guide future direction. There is no need for all jurisdictions to adhere to a more basic GLS framework to cater for states with few measures in place, nor do all jurisdictions need to aim for a model that is far from attainable. Even so, the overall aim of this policy framework is to encourage each jurisdiction to improve the safety of young drivers by working to improve their GLS models.

Figure 1. Proposed Australian GLS Policy Framework



Key elements of effective GLS models

Age of licensing

Policy recommendation:

- The older a person is when licensed the better. Measures to encourage older age licensing should be implemented, either by increasing the minimum age or other measures which serve to delay licensing until substantial supervised driving experience is gained.

When managing when and how a young person learns to drive, jurisdictions need to recognise the processes of adolescent development, and this should be considered in GLS models.

There is consensus in developed countries using GLS for novice drivers that 16 years is the appropriate minimum age to commence driving as a learner and this is supported by empirical evidence and by research on adolescent development (Senserrick & Williams, 2013; Keating & Halpern-Felsher, 2008). Most Australian jurisdictions set the minimum age when a person can apply for a provisional licence at 17 years. Crash evaluations identify young age as a risk factor and research shows that there are safety benefits in setting the age of solo driving at higher ages. Increasing the licensing age to 18 from 17 would produce a 20% reduction in crashes among 16-24 year olds (Department for Transport, Energy and Infrastructure, 2011).

Despite the road safety benefits, raising the licensing age can attract political and community pressure related to mobility. A lack of mobility can lead to educational and employment disadvantage, especially for those living in rural and remote areas. Measures that support increases in the actual age at which young people become licensed may be an alternative option to changing the minimum age for a provisional licence. Both New South Wales and Queensland reported increases in the median age young people are licensed after increasing the minimum learner period to 12 months.

Pre-licence experience

Policy recommendations:

- Australian GLS models should have a minimum learner permit period of 12 months.
- Extensive supervised driving experience should be encouraged and the minimum number of hours that are to be logged by learners should be a requirement of all GLS models.
- Supervised night time driving should be encouraged, and requirements for a set number of hours for supervised experience at night should be established.

Research shows that drivers tend to learn basic car control skills relatively quickly. However, it takes significantly longer to learn more complex cognitive abilities involving judgment, risk assessment and decision making that enables a novice driver to be safe across a wide range of potentially hazardous situations (McCartt et al., 2009).

Evaluations of increases in the minimum learner period from 6 to 12 months in Queensland and Victoria indicated positive road safety outcomes. Most Australian jurisdictions have a minimum 12 month learner period and this should extend to all jurisdictions.

Research suggests that setting a requirement for between 80 and 120 hours will have crash reduction benefits (Senserrick & Williams, 2013). Significant crash reductions were recorded in

Victoria and Queensland after they introduced a GLS with a requirement for 120 hours and 100 hours respectively. Victorian research found that during the latter phase of the learning period (after 80 or 90 hours) driving involves more challenging and complex situations. It is possible that without extensive supervised pre-licence driving, some learners do not experience this complex driving until they are driving solo.

Young drivers have a significantly higher crash risk when driving at night. Therefore some jurisdictions require a certain number of night-time supervised hours. Having supervised experience driving at night as a learner is important, and a GLS requirement for this ensures learners will gain some experience driving in dark conditions. There is no specific research evidence to prescribe how many hours this should be (Senserrick & Williams, 2013), but in general the more experience in a range of conditions the better.

Effective licence testing

Policy recommendations:

- On-road driving tests that are effective in discriminating between safer and less safe drivers should be administered prior to obtaining a P licence.
- Hazard perception tests should be utilised as part of the licensing process for GLS and ideally should be applied to progress from a Learner permit to a P1 licence.

Licence tests are an integral part of all licensing systems. The broad aim of licence testing is to provide an effective assessment of driving competence to determine if the novice driver is safe to progress from supervised (learner) driving to unsupervised (provisional) driving (Cavallo & Oh, 2008).

Some form of testing is part of all Australian GLS models, although the nature of the tests and when they are applied varies considerably. At the learner permit level, almost all jurisdictions require applicants to pass a road law knowledge test. While not evaluated extensively, this is widely regarded as appropriate. Tests to progress to a provisional licence vary across jurisdictions – some are on-road, some are competency based, and some test as part of a two stage learner period. There is no evidence to suggest one approach over another. However, an evaluation of the Victorian Drive Test showed performance was indicative of total leaner experience, particularly experience gained in challenging driving situations (Cavallo & Oh, 2008).

Computer based Hazard Perception Tests (HPT) are used in several states, and generally show some predictive validity (Senserrick & Williams, 2013). There is currently an Austroads project focusing on the best content of the HPT. Jurisdictions vary in when they apply the HPT – either before driving solo, or before moving from P1 to P2. Given that the crash risk of provisional drivers is highest during the first 6 to 12 months of driving, the HPT offers the greatest potential to assist young driver safety if it is administered prior to a provisional licence being issued.

Risk reduction measures

There is consistent evidence (Palamara et al., 2012) of an increased risk of crash involvement among young people associated with those:

- who drive late at night
- who are carrying peer aged passengers

- using mobile phones or texting while driving
- with a history of drink driving offences
- in their earliest months of licensure (e.g. less than 12 months), relative to more experienced young drivers
- who speed and particularly those who engage in high level speeding.

In order to minimise the negative impacts of youth risk taking, as well as their propensity to be over-confident and to over-estimate their driving ability, the environmental contexts that are associated with risky driving should be controlled (Palamara et al., 2012). One of the significant benefits of GLS approaches is that they provide a mechanism by which a novice driver's exposure to risky situations can be managed (Keating & Halpern-Felsher, 2008).

Late night driving

Policy recommendation:

- Restrictions on late night driving during the early provisional period have been shown to provide road safety benefits and need to be considered.

Research shows that crash risk is greater at night for all drivers and especially so for young and inexperienced drivers. The over-representation of young and novice drivers in night-time crashes is thought to be related to a combination of low traffic volume (and more opportunity to travel at high speeds), increased social activity, inexperience and decreased perceptual capacity (Kinnear et al., 2013). Reviews of the effectiveness of late night driving restrictions from US evaluations have found that it is associated with significant crash reductions. The longer the time period for which this restriction is applied (e.g. starting earlier and finishing later) the greater the crash reductions (Senserrick & Williams, 2013).

A lack of community support and understanding of the risks of late night driving have been raised. However, South Australia introduced a restriction successfully through by effective community consultation and communication, including highlighting the potential crash saving. UK based research also suggests that no evaluations of Graduated Driver Licensing have reported the employability of young people as being adversely affected (Kinnear et al., 2013).

In order for late night restrictions to be introduced as part of a GLS, community concerns about the potentially negative effect this may have on parents and employment opportunities for young people need to be addressed and the overall benefits clearly explained. It is also important that exemptions occur if the driver is with a supervising driver or carrying out essential activities.

Peer passenger restrictions

Policy recommendation:

- Restrictions on carrying multiple peer aged passengers during the early provisional period have been shown to provide road safety benefits and should be considered by all jurisdictions.

Research has shown that a young driver's risk of crash involvement increases incrementally with each additional peer aged passenger. Peer passenger restrictions are a common component of US based GLS models and have been associated with very significant reductions in fatal and injury crashes among young drivers (Senserrick & Williams, 2013). An interim evaluation of the Victorian GLS also found that a reduction in crashes with multiple passengers was recorded after this measure was introduced (Healy et al., 2012).

As with late night restrictions, it important that exemptions occur if the provisional driver is with a supervising driver or carrying out essential activities.

Mobile phone restrictions

Policy recommendation:

- Consideration should be given to reducing in-vehicle distraction during the entire P period, including the use of mobile phones.

The use of both hands-free and hand-held mobile phones has been found to increase crash risk, especially for inexperienced and young drivers who appear to have greater deficits in managing divided attention while driving. The rate of inattention-related crash and near-crash events decrease dramatically with age, with the rate being as much as four times higher for the 18-to-20-year-old age group relative to older groups (NHTSA, 2006).

Most Australian jurisdictions have restrictions on the use of mobile phones during the learner and provisional period. While there are no specific evaluations to determine the efficacy of this, the broader evidence about mobile phone use and increased risk among novice drivers is consistent.

It should also be recognised that technological advances and the take up of new devices by younger people is likely to outpace regulations. As such, the issue goes beyond the use of mobile phones to include many forms of portable or in-car devices that may cause distraction, especially for younger less experienced drivers.

Zero BAC requirements

Policy recommendation:

- Zero BAC requirements as part of the GLS have been very effective, and jurisdictions should consider ways to extend the zero BAC requirement.

Even small amounts of alcohol can increase crash risk and the risk of fatal crash involvement associated with alcohol is greater for young novice drivers than older experienced drivers.

All Australian jurisdictions have zero BAC limits for learner and provisional drivers and these have been shown to be effective in significantly reducing alcohol related crashes. A zero limit has been shown to be significantly more effective than low limits, such as 0.02 BAC (Senserrick & Williams, 2013).

The National Road Safety Strategy references the potential action of extending the zero BAC length as part of initiatives to improve driving licensing arrangements. Although this is thought to be difficult, one option could be to extend the restriction to the age of 21 by extending the P2 period to 4 years. Recent crash data from some Australian jurisdictions suggests that there may be benefits in extending the zero BAC requirement to 25 years (see further discussion later).

Length of provisional requirements

Policy recommendation:

- A longer provisional period has several benefits, such as a zero BAC requirement and lower demerit point threshold. Jurisdictions should consider having a total provisional period of 3 years and ultimately aim to have a 4 year provisional period.

The length of the provisional period ranges from 2 to 4 years across Australia. The minimum age at which a young person can obtain a full driving licence ranges from 19 years (in Western Australia) up to 22 years (in Victoria).

As all jurisdictions require a zero BAC for the entire GLS period, the primary benefit of longer provisional periods is the amount of time a young driver is required to have a zero BAC limit. In addition to this benefit, extended provisional periods mean that the young driver has a lower demerit point threshold before licence cancellation, and faces more stringent penalties for certain high risk offences in some jurisdictions.

Behaviour control measures

Policy recommendation:

- Lower demerit point thresholds for novice drivers are regarded as effective. Research into the impact that penalties and enforcement levels have on deterring young drivers from offending and/or re-offending as well as on the re-licensing rates would help jurisdictions develop the optimum approach.

In order to deter and potentially manage high risk young drivers, specific and more stringent penalties apply to young drivers in most jurisdictions under existing GLS models.

One commonly applied sanction is a lower demerit point threshold for both learner and provisional drivers. The evidence about the effectiveness of demerit point systems for all drivers is well documented (Diamantopoulou et al., 1997), although not specifically about young drivers in Australia. A recent evaluation of the increased sanctions for young drivers who offend in the UK found a reduction in the incidence of offending among young drivers (Kinnear et al., 2013).

In most jurisdictions, novice drivers can accrue no more than 4 or 5 demerit points in a year while under the GLS, although some have stricter systems with no more than 4 demerit points in three years. Additional measures include immediate licence suspension for any speeding offence (NSW), licence suspension for any breach of licence conditions or accrual of 4 or more demerit points (South Australia), and an interlock for novice drivers with a BAC of 0.07 or higher (Victoria).

As there have been no evaluations of the effect of these measures, what specific sanctions or penalty programs should apply for novice drivers under an optimum GLS model are not known. Jurisdictions need to balance the anticipated deterrent effects of harsher penalties with the effectiveness of the sanction on offenders. Some further evaluation is needed to establish the optimum approach for this, as well as additional penalties for P drivers.

Access to licensing

Policy recommendation:

- The overall safety of all young people should be the key imperative in all programs to assist young people obtain a licence. Governments need to support programs to assist disadvantaged learners progress through the GLS, ideally helping them to meet the key requirements of the GLS.

- Indigenous communities require specific support to achieve licensing which go beyond (necessary) support for supervised driving.

Certain groups in the community can have difficulty meeting the GLS requirements, which can have a significant impact on their access to employment, education, training, health care, family, cultural and recreational activities. Groups identified as facing particular disadvantage in terms of access to licensing are Aboriginal people, people from CALD backgrounds and people from low socio-economic backgrounds. Difficulties for these groups include access to supervising drivers, language barriers, lack of access to identity documents and the cost of driving lessons, fuel and licensing fees (NSW Audit Report, 2013; Department of Transport, 2012a & 2012b).

Jurisdictions need to balance the safety benefits for the majority of young people (and the wider community) with the specific needs of smaller disadvantaged groups. It is important that safety is not downplayed, but flexibility in approaches and a broader appreciation of licensing challenges is necessary. Coordinated support across government agencies essential to achieve this.

Several jurisdictions (including Victoria and Tasmania) have implemented programs or initiatives to try to assist disadvantaged groups to meet the requirements of the GLS, especially the minimum number of supervised driving hours. Other states have programs that focus more on other barriers to licensing experienced by disadvantaged groups and include a focus on road safety education.

Exemptions may now be granted to an Aboriginal person who resides on certain Lands, including a reduced number of hours of supervised driving and less time at particular stages of the GLS. The key method proposed to deliver the driver licensing scheme on the Lands is individual case management via Aboriginal program support officers operating on the ground.

Areas requiring further research

There are a number of measures that may have potential but further research is needed to confirm and quantify the benefits of these measures. Subsequently these are not currently included in the GLS policy framework. Suggested research includes:

- *Level and experience of supervising drivers* – Determining whether there are any benefits in restricting the type of people that can supervise learners (years of experience and license cancellations) and whether restricting the nature (and in effect the number) of people who can supervise has a positive effect on road safety.

- *Online log books* – Exploring the potential of on-line learner log books which may not only be preferred by learners, but may provide a valuable source of information about the nature of driving that learners undertake and also enable effective and timely communication with learners and their supervisors.

- *Licensing requirements to progress to full licences* – Quantifying the road safety value in requiring a clean driving record or the completion of an exit test before graduating to a full licence.

- *Extending the Zero BAC requirement* – Reviewing the extent of drink driving among young fully licensed drivers – in terms of infringements and crash involvement to determine whether extending the zero BAC is justified and how this could practically be implemented in the community. The current Austroads project will provide guidance here.

- *Penalties for novice drivers* – Determining what the optimum protocol for enhanced penalties is for novice drivers.

- *Driving programs as part of the GLS* – Undertaking detailed evaluations of the road safety benefits of safe driving programs that are designed to be part of the GLS process.

- *Nature and value of support programs for disadvantaged* – Investigating the level of investment required to support disadvantaged young people progress through the GLS; what are the additional social benefits and what are the consequences of not having these programs or measures.

Achieving improved GLS policy

The key purpose of a GLS is to address the issues impacting on the road safety of young drivers. These are age, experience and risk taking. It is widely acknowledged that changing licensing policy is often a long and hard-fought process. The key elements of achieving improved GLS policy rely on having evidence of the effectiveness of specific measures, and having community support or acceptance of any proposed changes.

In order to continue to improve and enhance Australian GLS models, jurisdictions will need to continue to develop a strong evidence base for elements in the GLS, reviewing key areas of young driver safety, understanding potential crash reductions of potential measures and evaluating the effectiveness of implementing them.

Engaging with the community and key opinion leaders is necessary to garner the level of support needed to improve young driver licensing policy. In developing the GLS framework it has also been important to acknowledge the efforts jurisdictions have already gone to in implementing GLS elements in their licencing systems. Road Ministers from all jurisdictions have now endorsed the GLS policy framework which is a very positive first step. It is important that jurisdictions develop effective communication programs to inform the community of the need to address young driver safety and of the evidence that shows how certain elements of a GLS can lead to less young driver deaths and injuries.

The GLS framework gives jurisdictions good guidance on what more they can do to address the issues through the licensing system to get better safety outcomes.

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Rapid deployment of Intelligent Speed Adaptation in New South Wales – The story of Speed Adviser

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Abstract

Speeding is a contributing factor in around 40% of all fatal crashes in New South Wales. Australian road safety research suggests that Intelligent Speed Adaptation (ISA) technology has the potential to reduce fatal and serious injury crashes by around 19%. Last year the European Transport Safety Council released the results of a comprehensive assessment of eight different driver support technologies that showed that Intelligent Speed Assistance (ISA) would save the most lives in Europe. In February 2014, Transport for NSW released its own smart phone ISA application, Speed Adviser. This makes NSW the first jurisdiction in the world to provide ISA technology free of charge to its drivers and riders. Over 80,000 downloads of Speed Adviser have been recorded since the application became available, which makes this one of the most rapidly deployed road safety technology countermeasures in history. Speed Adviser is an early indication of the potential benefit of smart phone based road safety countermeasures.

Extended Abstract

Australia's National Road Safety Strategy states that speed is highly implicated in a large proportion of serious casualty crashes. Measures that address speed can also mitigate the severity of crashes no matter what was the original cause. Speeding is a contributing factor in around 40% of all fatal crashes in New South Wales (TfNSW 2015).

Despite the clear evidence that complying to appropriately set speed limits reduces the risk of being involved in an injury related crash, speeding is a major behavioural issue for road safety agencies and authorities.

Intelligent Speed Adaptation (also known as Intelligent Speed Assistance) technology refers to in-vehicle systems which assist drivers to keep to or below the speed limit. By using Global Navigation Satellite System (GNSS) technology and on-board maps which are linked to a speed zone database, the ISA system 'knows' where the vehicle is and what the speed limit is for that road at all times. The ISA system warns drivers via visual and audible feedback if they exceed the speed limit, and/or prevents the vehicle from exceeding the speed limit.

Following an extensive 1.9 million kilometre trial of the technology in NSW throughout 2009 and independent modelling by the Centre for Automotive Safety Research in Adelaide, it was found that the deployment of ISA had the potential to reduce fatal and serious injury crashes across Australia by around 19% and save 200 lives a year on the Nation's roads (Wall 2011).

In April 2014, the European Transport Safety Council released a comprehensive assessment of eight different driver support technologies which showed that Intelligent Speed Adaptation (ISA) would save the most lives (ETSC 2014). The

ETSC stated that ‘assisting’ ISA, that warns drivers of speed limits and assists the driver to adapt to the correct speed, should be introduced on all professional vehicles such as vans, lorries and buses as part of the EU’s ongoing review of general vehicle safety rules, and, in time, for all new vehicle types.

In February 2014, the NSW Roads Minister launched Speed Adviser, an advisory ISA smart phone application running on the IOS and Android mobile operating platforms. The application cost around $90,000 to build and was developed from the ground up by in-house developers working for Roads and Maritime Services and Transport for NSW.

The deployment of ISA through a smart phone application by a Government based road safety agency is a world first. The application is provided free of charge. Speed Adviser includes a database of all speed zones in New South Wales and covers more than 225,000 km of road network length. Over 81,000 downloads of Speed Adviser were recorded in the first 14 months since the application became available, which makes this one of the most rapidly deployed road safety technology countermeasures in history.

Speed Adviser took more than two years to develop, with careful attention paid to the Human Machine Interface (HMI). A key challenge facing developers was making the application an effective speeding countermeasure whilst minimising distraction from other critical tasks associated with driving.

Due to privacy concerns expressed around tracking of road users by Government road safety enforcement agencies, at the time of the initial ISA trial, it was decided at the outset that the Speed Adviser application would not collect any live data from users. This required all speed zone data to be built in to the application as it would not be able to be downloaded as the vehicle travelled along the network. This meant the application required a minimum of 250Mb of space to be installed on the smart phone. It also required the phone to be connected to a wireless network for the initial download and subsequent updates. This decision has also limited the frequency of speed zone updates that can be made to the application. There have been three updates to the application made since its initial launch on iOS and five updates on the Android platforms.

Feedback from users of the application has been generally very positive. Out of the 65 reviews posted on Google Play, 38 have rated the application four stars or above. In iTunes 17 out of 33 customers have rated the application at four stars or above. The following comments were posted by customers that rated the application four stars or above:

- NSW Government’s best gift to motorists, ever!
- This app is great especially where there are multiple speed zones, entering a road and there are no speed signs and when it is easy to miss a speed sign in heavy traffic.
- Safe Driving heard about it from a listener on ABC what a great idea.

- Great app . How often have you just wondered what the speed limit is? Now you can know all the time.

Of the customers that rated the application 2 stars or below their dissatisfaction related to the following areas:

- wanted the app to display their current speed rather than warning them to slow down
- battery power used by the phone when running the app
  speed zone accuracy
- the absence of any tolerance to speeding before a warning was issued
  issues associated with sound warnings when using other apps or Bluetooth networks..

A number of user recommended changes have been implemented since the launch of the initial application. These have included:

- allowing users to adjust the volume of warnings
- providing advanced warnings of school zones
- adding a quit button to allows users to shut down the app more easily
- providing limited variable speed zone information

From February 2014 until June 2015 only 25 issues relating to speed zone accuracy have been received by Transport for NSW through our application support email account.

The initial methodology chosen to launch the Speed Adviser application had a major impact on downloads of the application across smart phone platforms. When the app was originally launched it was only available on the iOS platform through iTunes. It was eight weeks before an Android version of the application was released on Google Play. An analysis of downloads across both platforms indicate 21 iOS users for every single Android user. Download statistics show that 13,300 users subscribed to the application on iTunes on the night that the exclusive story went to air on Channel 9 News. Whilst paid on-line marketing of the application has continued throughout the year, it is clear that the promotion of the app via a news network exclusive was a very powerful call to action for customers.

One of the biggest advantages of using smart phone platform to deliver a road safety technology countermeasure is related to cost effectiveness. The initial ISA device trialled in NSW in 2009 cost around $1,500 to install in a vehicle and a further $10 per month data charge for each device. Research conducted as part of the NSW ISA trial showed that participants that valued having an ISA device would not be willing to pay more than $249 to have the system installed in their vehicle (RTA 2011). Through the use of smart phone technology, Transport for NSW has been able to provide ISA free of charge to drivers, an impossible task only four years ago.

In 2010 when the NSW ISA trial was completed about 24 per cent of mobile phone users owned a smart phone. By 2017 this is predicted to grow to 80 per cent. (Statista 2015). With the computing and sensing capability of smart phones improving year by year, the opportunities to develop new road safety applications are continuing to evolve for road safety agencies. The smart phone of 2020 will have a range of sophisticated sensors including location technology that can read a users facial expressions and as well as locate their position to within 10 cm.

This means that the smart phone or wearable device of the future will be able to detect and warn the driver that they are becoming drowsy or are unwell, following too closely to the vehicle in front, or about to collide with a pedestrian. Should a crash happen the smart phone will call emergency services for help and even provide first responders with information on the types of injuries and current condition of vehicle occupants.

The potential for distracting drivers through smartphone applications is a growing issue for road safety agencies. The challenge for road safety professionals and legislators is to manage the risks of smart phones whilst maximising the safety benefits of these sophisticated small computers. Speed Adviser is an early indication of the potential benefit of smart phone based road safety countermeasures.

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The New Zealand Alcohol Interlock Program: a review of the first year as a sentencing option for high risk drink drivers

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Abstract

Despite decreasing overall convictions for drink driving 2009-2012 in New Zealand (NZ), convictions for high risk (repeat or high level) drink driving increased. Evidence shows alcohol ignition interlocks reduce drink driving compared to existing sanctions (licence disqualification and fines). In 2011 legislation enabled the introduction of an Alcohol Interlock Program (AIP) for high risk drink drivers in NZ. This paper reviews the AIP in its first year as a sentencing option for high risk drink drivers. Ministry of Justice and NZ Transport Agency data was reviewed and stakeholders and participants of the AIP provided information. For the period 10 September 2012 to 9 September 2013 there were 23,362 drivers convicted of drink/drug driving. Of these, 11,692 (50%) met the criteria for the AIP: 6,639 repeat convictions and 5,053 first time convictions over double the legal limit. Only 228 offenders received an alcohol interlock sentence in addition to other penalties (2% of those eligible), far fewer than expected. Stakeholders report multiple barriers to uptake of the AIP: cost; more attractive alternative sentences (shorter duration, shorter stand-down period, less cost); legal loopholes (e.g. competing 'mandatory' sentences); and use of the Zero Alcohol licence (introduced as part of the AIP) as a stand-alone alternative. The AIP has been involved in High Court Appeals, further reducing judges' confidence in this option. A mandatory AIP sentence for this cohort of drivers would bring NZ into line with international and Australian jurisdictions.

Introduction

Despite sanction based initiatives (including licence disqualification, community sentences, fines and imprisonment), rates of repeat and high level drink driving convictions have increased every year in New Zealand (Waters, 2013). The New Zealand Ministry of Transport, in its Safer Journeys road safety strategy, identified this group as high risk, and a high priority area of concern. In 2011, to tackle this problem and based on the evidence of alcohol ignition interlocks effectiveness to do so, Parliament passed legislation allowing for the introduction of an Alcohol Interlock Program (AIP) in New Zealand for repeat drink drivers and some first time drink drivers. By introducing alcohol interlocks and Zero Alcohol Licences (ZAL) to New Zealand the *Safer Journeys* strategy aims to reduce the impact of drink driving on our roads. In New Zealand, alcohol interlocks are a sentencing option for judges for repeat drink-drivers, defined as 2 or more convictions for drink-driving in a five year period, or high level first-time drink-drivers, defined as over 800 mcg alcohol/L of breath, or over 160 mg alcohol per 100 mL of blood. For drivers over 20 years old, the drink-driving limits are 400 mcg alcohol /L of breath or 80 mg alcohol/ 100 mL of blood. There is a zero alcohol limit for drivers under 20. The Regulatory Impact Statement 'Completing the actions to address alcohol-impaired driving' (MoT, 2010) identified that the potential road safety benefits from the use of alcohol interlocks for repeat offenders and high level first-time drink-drivers would be a reduction of one to two lives and 25 injuries every year from 2013/14. In terms of the social cost of road injuries, the reduction would be $10 million each year. Furthermore, the potential reduction in the social cost of harmful alcohol use will be $2.9 million each year from 2013/14. International experience has found the alcohol ignition interlock to be highly effective in preventing instances of drink driving (Waters, 2012) and the prevention of harm from such behaviour. Due to the success of these devices international practice is moving towards their use for all detected drink drivers. In NZ the interlock is used as a sentencing option for judges and the AIP is administered by the NZ Transport Agency.

Objectives

This paper reviews the New Zealand Alcohol Interlock Program (AIP) and details the use of the AIP sentence in its first year as a sentencing option from September 2012 to September 2013.

Methodology

Data was extracted from the Ministry of Justice's Case Management System (CMS) to determine how many offenders in the study period would be eligible for an alcohol interlock, and how many actually had an interlock sentence. Crash and licence status data was also provided by the NZ Transport Agency. Stakeholders of the AIP were interviewed and AIP participants invited to respond to questionnaires. This paper also provides general information on the AIP and also informs on stakeholder and participant views. The paper also provides other relevant data relating to the AIP.

Key Outcomes

Table 1. Sentences of those eligible for interlock by percentage and number of previous convictions September 2012 - September 2013

Number of previous convictions	Percentage of custodial sentences	Percentage of home detention sentences	Percentage of other community sentences	Percentage of AIP sentences
0	1.7	1.1	24.0	0.7
1	7.3	5.4	60.1	2.6
2	15.7	12.2	65.0	3.6
3+	28.6	16.5	48.4	4.1
Sentence Percentage of total offences	4.1	2.9	35.0	2.0

From 10 September 2012 - 9 September 2013, 23,362 drivers were convicted of drink/drug driving. Of these convictions 11,692 offenders met the criteria for the use of the AIP as a sentencing option. 6639 of the individuals convicted were repeat offenders and 5053 were high level first time detected offenders. 228 offenders received the AIP Sentence in addition to other penalties; that is 2% (Table 1) of those offenders eligible for the AIP, the rest received only penalties used previously for drink driving offences, including fines and licence disqualification (which are not represented in the percentages in Table 1). Since September 2012 to March 2014, 198 offenders have been issued with an Alcohol Interlock Licence (AIL). As at March 2014, 1 offender was convicted of an alcohol/drug driving offence since their AIL was issued. The AIP has incorporated some features that have been recognised as best practice. The NZ Transport Agency reported no problems with the administration of the program. Participants of the AIP report that the device stops them from drink driving and

impacts on their drinking habits. The costs involved with the interlock sentence appear to limit their use to those that can afford it. Interlock provider SmartStart report that they had installed 126 interlocks as of March 2014, with 5 participants successfully exiting the program. SmartStart reports that as of March 2014 their devices had stopped 599 attempts to drink and drive. The other interlock provider (there are two in NZ) Draeger Safety Pacific had 55 interlocks fitted by the same date, had 3 participants successfully exit the program and reports stopping 390 attempts of drink driving.

The interlock sentence has been involved in High Court Appeals. Stakeholders report multiple problems with the interlock sentencing option including: unclear or conflicting legislation**;** the ongoing use of existing penalties; the ready availability of the limited licence option; the costs to participants; and the perception that it is a soft option.

Between the 10 September 2012 and the 26 May 2014, 24.5% of the drink drivers, being granted a limited licence, were twice the legal limit. The introduction of a mandatory sentence of AIP for this cohort of drivers must be seriously considered to bring New Zealand into line with other international and Australian jurisdictions.

Discussion

The AIP was introduced to tackle the cohort of drink drivers for whom the application of previous penalties available had resulted in further reoffending. The evidence of the interlock to stop instances of drink driving is overwhelming and the reason they were introduced to New Zealand. More than half the drivers convicted at court in 2013 were repeat or high level first time detected drink drivers. Whilst the total number of detected offenders is dropping we are seeing increasing rates of detection of high risk/high priority drink drive offenders. The barriers to participation in the interlock program are numerous and if left in its current state it will fail to impact on the harm caused by high risk drink drivers. Continued use of the availability of the limited licence for some drink drivers needs to be reviewed to ensure greater public safety. The introduction and use by the judiciary of a stand-alone Zero Alcohol Licence may also be problematic; while perceived as further punishment there is no evidence it provides public safety. It has been reported that the interlock program is seen as a ‘soft option’ and that the previous sanctions (that are still failing) are preferred. This reasoning is not supported by evidence, and fails to take into account the safety of the public. Participants of the interlock program, who contributed to this paper, report on the punitive nature of the device as well as its ability to change not only their drink driving, but also their drinking behaviour. That there is no assurance of the interlock device being fitted once an interlock licence has been received is also concerning. The interlock sentence also appears to be limited to those who can afford it.

NZ cannot reduce the amount of repeat and high level first time detected drink drivers and reduce the harm they cause, by continuing to use current sanctions. The introduction of a mandatory sentence of AIP for this cohort of offenders must be seriously considered to bring NZ into line with other international and Australian jurisdictions. A review of the AIP in 2015; to include rehabilitation and monitoring measures along with a review of the offences and penalties regime, announced by the Ministry of Transport, may be a timely intervention to bring together the previous piecemeal attempts at tackling high risk drink drivers in NZ. It is suggested that any review of the AIP take advantage of the information contained in this report.

Conclusion

The introduction of a mandatory sentence of AIP for this cohort of drivers must be seriously considered to bring New Zealand into line with other international and Australian jurisdictions.

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New Zealand Youth Traffic Offences and Traffic Offending: Phase 1 Data Gathering

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Abstract

The 'New Zealand Youth Traffic Offences Project' aims to identify interventions that reduce youth traffic re-offending, improve road safety and reduce costs to the justice system by answering two research questions: Is traffic offending a leading path into the criminal justice system for young New Zealanders? And are there more effective interventions than standard penalties at reducing re-offending and improving road safety outcomes? This paper reports on Phase 1 of that project: to scope the extent of youth traffic offending, and identify the most common infringements and offences and sanctions, so as to focus further work. Government agencies collaborated to create a unique, broad brush picture of the path of youth traffic offending through the justice system from the Police Infringement Processing System database, Driver Licence Register (demerit points), Collections (fines) data and Ministry of Justice Case Management System data. Data were at a national level for youth age 14-19, from 2009-2013 (5 calendar years). The main findings of the paper were:

- Total youth traffic and non-traffic offending decreased significantly.
- The licensed youth driving population decreased by 30.4%.
- Infringements are the largest response to youth traffic offending.
- 68.3 % of all total infringements are referred to Court Collections.
- 72 % of all youth High Risk Driving Offences are Graduated Driver Licence System breaches.
- 54 % of first time, and 53 % of total, youth traffic offences were alcohol related.
- In 2009, fines totalling $42,054,645 were referred to Collections from Police traffic infringements.

Aims and Objectives Data Gathering Phase 1

This paper reports on Phase 1 of the 'New Zealand Youth Traffic Offences and Offending Project' (the YTO project). Its purpose is to: identify relevant data sources and report on levels of youth traffic offences and offending.

Methodology

A high-level scan was undertaken of existing information and readily accessible data systems to scope the problem and identify areas for future work. Data sources were limited to: Crash Analysis System (CAS), Driver Licence Register (DLR), National Intelligence Application (NIA), Police Infringement Processing System (PIPS), and Ministry of Justice Case Management System (CMS). The stakeholder Reference Group comprised: NZ Police, Ministry of Transport, Ministry of Justice, NZ Transport Agency, Department of Corrections and New Zealand Automobile Association Research Foundation. To ensure that the YTO Project was completed within timeframe and budget, and after consultation with the Reference Group, the data was narrowed to: youth age bands (14-19, where available), infringements and offences to identify the most common (e.g. drink-driving, licence breaches, speed, vehicle offences, dangerous driving), study period 2009-2013 (last 5 calendar years), national data.

Information Sharing and Data Limitations

The collaborative involvement and input of government organisations were vital to the project. There were two major changes to legislation in the years being reviewed and these changes need to be recognised and their impact on interpretation of trends over time should be explicitly noted when quoting the relevant data and comments. Firstly, the Learner licence age was raised, from 15 to 16 years of age, in August 2011, leading to a meaningful drop in numbers of youth licensed. These reduced numbers flow through all tables and figures and need to be acknowledged in any discussion of time trends.

Secondly, in August 2011, a new infringement offence was introduced for youth (under 20 years of age) driving with between zero and 30mcg alcohol/litre blood (0.03 BAC). Higher levels of alcohol (over 0.03 BAC) continued to attract Court penalties.

Key Findings

Total youth traffic and non-traffic offending decreased significantly from 2009-2013. The licensed youth driving population decreased by 30.4% from 2009-2013. Infringements are the largest component of the records on youth traffic offending. Graduated Driver Licence breaches account for 72 % of all youth High Risk Driving Offences for 2009-2013. 68.3 % of all total infringements are referred to Court for collection. 54 % of first time youth traffic offences 2009-2013 and 53 % of total youth traffic offences 2009-2013 are alcohol related. During the review of Court outcomes data it became apparent that a new data base was held by the 'Collections' Unit of the Ministry of Justice. This information has since been added to this paper as an addendum. The amount of monetary fines imposed for collection for Police infringements referred to Collections in 2009 was $42,054,645. By 2014, 54% of the total monies imposed for Police referred infringements to Collections in 2009 had been paid, 41% had been remitted and 5% was still outstanding. 64 % of the total amount of monies remitted were replaced with alternative sentences. 56 % of the total amount of monies remitted were replaced with the alternative sentence of Community Work.

Discussion

This is a comprehensive review of the relevant data on youth traffic offences and offending in New Zealand over the period 2009-2013. It documents and organizes a unique and detailed set of data within the context of the relevant regulation and legislative information. The report has been able to focus on the overlapping areas of licensing, offending and offenders. This could only have been undertaken with a collaborative and supportive association with all the relevant government departments involved. This is an exhaustive review of offence statistics related to young people aged 14-19 years over the period 2009-2013. The supplementary data contained in the addendum paper provides material on fines referred to Court for collection and their outcomes. The collaborative involvement of government analysts was critical to the project. The data on first proved offending (serious offences that require a Court outcome), identifies significant reductions from 2009 to 2013. These reductions flow through all the data and also include significant reductions in all traffic offending including adults. Given no reduction in enforcement resourcing over this same period, this is a remarkable finding, which hints at successes in the New Zealand settings for offending that are worthy of further research. The report has not, at this stage, proposed any explanation of these reductions but discussions with the Reference Group and the analysts involved in the project suggested that the use of Policing Excellence (PE) could play a major role in this phenomena. PE is the largest, strategically significant and operationally relevant change programme undertaken by New Zealand Police to date. PE changed the face of policing in New Zealand, shifting the emphasis away from being predominantly reactive and offender focused, to being proactive, prevention and victim focused, resulting in a modern, mobile and accessible Police service.

The data contained in the paper shows that 54 % of first time youth traffic proved offending 2009-2013 and 53 % of total youth traffic cases at Court 2009-2013 are alcohol related. From 2009-2013 54.1 % of disqualifications for drivers aged 15-19 are for alcohol related offences. The early impact of the introduction of the youth zero alcohol limit are reflected in the data contained in this paper and could provide an opportunity for an early evaluation of the zero limits effectiveness. Further detailed research on youth drink and drug driving in New Zealand would be desirable.

The data shows that Police infringements are the largest component of youth traffic offending. The majority of infringement fines imposed are referred to Court unpaid. 68.3 % of all total infringements are referred to Collections after the payment period (56 days) had expired. Further research on the Collections data, particularly a review of the use of infringements and the payment methods involved, may be of benefit in informing on its efficacy as a response to youth traffic offending.

A Graduated Driver Licence System (GDLS) was introduced to NZ to reduce the exposure of inexperienced drivers to high risk situations. GDLS breaches account for 72% of all youth High Risk Driving Offences for 2009-2013, 26.9% of all youth traffic offences 2009-2013 and 3% of total youth and adult traffic offences 2009-2013. From 2009-2013 97.1 % of youth GDLS breach offences resulted in an infringement offence of which 72.8 % was referred to Court unpaid. Further research on the use of the infringement based response for GDLS breaches and information on international initiatives/interventions regarding this type of offending would be desirable.

The first time youth traffic offender re-offending rates are high (though absolute numbers are low), and the effectiveness of the current penalties regime for our cohort of offenders may benefit from a review. It is suggested that the current use of rehabilitative efforts and technologies, such as alcohol interlocks, as a sentencing option for our cohort of offender should be reviewed. An international literature review of initiatives/interventions used for youth traffic offenders across all traffic offence types may provide useful information for any such reviews undertaken.

Regarding the question 'Is traffic offending a leading path into the criminal justice system for young New Zealanders?' If the term path is used as a first appearance at Court then the data contained in this paper would suggest that the answer is yes, with 41% of all proved first offending being traffic offences in 2009 and 46.4% in 2013. Further research is required to identify whether there are more effective interventions than standard penalties at reducing re-offending and improving road safety outcomes.

Signs of driver sleepiness and risky sleepy driving behaviours: the associations with demographic, work and sleep-related factors

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Abstract

Driving while sleepy is regarded as a substantial crash risk factor. Reducing the risk of sleep-related crashes predominately rests with the driver's awareness of experiencing signs that are common when sleepy; such as yawning, frequent eye blinks, and difficulty keeping eyes open. However the relationship between the signs of sleepiness and risky sleepy driving behaviours is largely unknown. The current study sought to examine the relationships between drivers' experiences of the signs of sleepiness, risky sleepy driving behaviours, and the associations with demographic, work and sleep-related factors. In total 1,608 participants completed a questionnaire administered via a telephone interview that assessed their experiences and behaviours of driving while sleepy. The results revealed a number of demographic, work and sleep-related factors were associated with experiencing signs of sleepiness when driving. Signs of sleepiness were also found to mediate the relationship between continuing to drive while sleepy and having a sleep-related close call event. A subgroup analysis based on age (under 30 and 30 years or older) found younger drivers were more likely to continue to drive when sleepy despite experiencing more signs of sleepiness. The results suggest participants had considerable experience with the signs of sleepiness and driving while sleepy. Actions to be taken from this research include informing the content of driver education campaigns regarding the importance of the signs of sleepiness. Working together to educate all drivers about the dangerousness of driving when experiencing signs of sleepiness is an important road safety outcome.

Introduction

Driver sleepiness is a substantial contributor to road crashes with current estimates suggesting sleepiness is associated with 19-34% of all fatal and severe crashes (Connor et al., 2002; Herman et al., 2014; Nabi et al., 2006). Most crashes are multifactorial in nature and given the potential overlap with sleepiness and several risky driving behaviours (Watling, Armstrong, & Smith, 2013), sleepiness could also be associated with a number of crashes assigned to other risky driving behaviours. Reducing the risk of sleep-related crashes predominately rests with the driver's awareness of experiencing signs of sleepiness.

The extant literature examining the signs of sleepiness has utilised laboratory, simulator, or questionnaire designs. Studies that have examined the awareness of the signs of sleepiness with laboratory vigilance studies have shown that as levels of sleepiness increases across a night of testing, so too does the number of sleepiness signs being reported by participants increase (e.g., Gillberg, Kecklund, & Åkerstedt, 1994; Kaplan, Itoi, & Dement, 2007). Specifically, Kaplan et al. (2007) demonstrated that participants experienced more signs of extreme sleepiness prior to a microsleep event than when no microsleep occurred. These studies suggest that there is a progression of the signs of sleepiness experienced with increases of sleepiness.

To date, only a few studies have examined the signs of sleepiness and their associations with sleepy driving behaviours with driving simulators. Nilsson, Nelson, and Carlson (1997) examined the occurrence of several physical and psychological signs of sleepiness by participants when driving in a simulator. Similar to the laboratory studies, the longer the duration of driving the more signs of sleepiness were reported by participants. Recently, a driving simulator study by Howard et al. (2014) revealed that participants reported experiencing the signs of sleepiness more frequently as physiological and subjective sleepiness increased and this was also associated with greater levels of impaired driving performance. Signs of sleepiness that were specifically associated with severely impaired simulated driving performance were related to visual disturbances (e.g., struggling to keep your eyes open) and overt signs of sleepiness impaired driving performance (e.g., difficulty maintain correct speed). Considered together, the studies presented suggest that as physiological and subjective indices of sleepiness increase so too does the number of signs of sleepiness experienced and this increase also corresponds to impaired simulated driving performance. Most importantly, these studies demonstrate that drivers are capable of perceiving the signs of sleepiness.

An aspect of drivers' experiences with the signs of sleepiness that has not been thoroughly examined is the association between individual factors and experiencing signs of sleepiness. Nordbakke and Sagberg (2007) examined the association between specific signs of sleepiness and demographic factors (sex and younger and older drivers) as well as falling asleep versus being close to falling asleep. Younger drivers were more likely to report experiencing early signs of sleepiness (e.g., yawning, more frequent eye blinks) and some extreme signs of sleepiness (i.e., difficulty concentrating on driving, dreamlike state of consciousness) than older drivers. While the findings from this study are informative, a number of other individual factors (apart from demographic factors) have been previously found to be associated with sleepy driving behaviours and thus, could be associated with experiencing signs of sleepiness. Individual factors that have been associated with sleepy driving include demographic factors such as education (Sagberg, 1999) and the number of hours driven per week/yearly mileage (Radun, Radun, Wahde, Watling, & Kecklund, 2015). Being a shift worker (Di Milia, 2006) and a professional driver (Carter, Ulfberg, Nyström, & Edling, 2003) are factors that expose the individual to greater levels of sleepiness and hence more opportunities to experience the signs of sleepiness. Sleep-related factors could also be associated with experiencing more signs of sleepiness, including experiencing frequent daytime sleepiness or poor sleep quality (Bartlett, Marshall, Williams, & Grunstein, 2008). Last, drivers that have previous experience with risky sleepy driving behaviours, such as driving while sleepy and having a sleep-related close call, are potentially more likely to have experienced signs of sleepiness.

Reducing the risk of sleep-related crashes predominately rests with the driver's awareness of experiencing signs of sleepiness. As such, understanding the associations between individual factors, risky sleepy driving behaviours, and experiences of the signs of sleepiness is an important undertaking for road safety. Therefore, the first aim of the study was to examine the association between demographic, work and sleep-related variables with the signs of sleepiness. The second aim was to examine the relationships between signs of driver sleepiness, continuing to drive when sleepy and sleep-related close calls. The third aim sought to determine differences between younger (17-29 years of age) and older (> 30 years of age) individuals as well as between females and males regarding risky sleepy driving behaviours and the main study variables.

Method

Participants

Participants were required to be aged 17 years or older, to hold a current drivers licence and to drive a vehicle (work or private) more than one hour per week. These inclusion criteria were chosen to ensure that participants had sufficient on-road driving experience. Altogether, 1,608 participants took part in the study.

A representative sample of drivers from New South Wales and the Australian Capital Territory was obtained based on the stratification of vehicles registered located in the statistical divisions. The statistical divisions are a general purpose spatial unit and are the largest and most stable spatial unit within each state/territory of Australia (Australian Bureau of Statistics, 2011). The sample was also stratified based on age, with half of the participants below the age of 30 years, as well as sex, with equal numbers of males and females to ensure the results were not biased from under or over-sampling of demographic variables.

Measures

The first section of the questionnaire recorded demographic information such as age, sex, and education level. Following this, participants were asked about any previous sleepy driving experiences in the last five years. The relevant peer reviewed literature concerned with signs of driver sleepiness was reviewed and eight signs of driver sleepiness were utilised. They included physical and psychological signs (e.g., yawning, changing position frequently frequent eye blinks, difficulty keeping eyes open, and a dreamlike state of consciousness) and signs of sleepiness associated with vehicle control (e.g., difficulty concentrating on driving, slower reaction to traffic events, and increased variation in speed). The remaining items asked if participants had in the last five years, continued to drive when sleepy and if they have had a sleep-related close call. Participants responded to these questions 'yes' or 'no'. Participants were then asked questions relating to the number of hours driven per week, whether they were a professional driver, or a shift worker. Finally, questions were included that concerned participants sleep health-related variables such as if they had difficulty getting to sleep (yes or no), the number of hours slept per night, quality of their normal sleep (4-point Likert scale: 1-poor to 4-excellent), and if they experienced frequent daytime sleepiness (yes or no).

Procedure

The research protocol was approved by the University Human Research Ethics Committee. An independent data collection organisation was commissioned to collect the data. The study data was collected via a telephone surveying methodology, using a Computer Assisted Telephone Interview system. Interviews that took place during the weekdays were conducted between 16:30 to 20:30 and on the weekends were conducted between 09:00 and 17:00. Participants were sourced from the Association of Market and Social Research Organisations Random Digit Dialling system. Participants were first read an introductory statement that explained the purpose of the study and that responses were completely confidential. Informed consent via a verbal confirmation from the participant was obtained for all participants. In total, a response rate of 17.31% was achieved.

Statistical Analyses

To examine the first aim of the study, the association between individual factors and experiences of signs of driver sleepiness, a hierarchical linear regression was performed. The outcome variable was the summation of the participants' experiences of specific signs of sleepiness with the predictor variables being the demographic, work and sleep-related variables. To examine the second aim regarding the relationships between signs of driver sleepiness, continuing to drive when sleepy and sleep-related close calls, a mediation analysis was performed. The relationships between continuing to drive when sleepy and sleep-related close call with signs of sleepiness as the mediator variable were tested with the procedure designed by Hayes (2013) with the significance of the indirect pathways assessed with bootstrapping. The third aim utilised Mann-Whitney U and Chi-squared analyses to determine differences between younger (17-29 years of age) and older (> 30 years of age) participants as well as between females and males for the main study variables.

Results

Signs of Sleepiness Descriptives

Table 1 displays the proportion of participants that had previously experienced signs of sleepiness and the descriptive statistics (means and standard deviations or percentage) for the study variables. It can be seen that over half of the participants had previously experienced yawning, changing position frequently, frequent eye blinks and difficulty concentration on driving in the past. Yawning, an early sign of sleepiness was the most reported experience; with dreamlike state of consciousness the least experienced sign of sleepiness. On average, participants reported having previously experienced four of the eight signs of driving sleepiness, with a moderate amount of variability. Approximately two-thirds of participants had previously continued to drive when sleepy in the last five years with 15.79% of participants reported previously having a sleep-related close call in previous five-year period.

Table 1. Descriptive statistics of the main study variables

Study variables	Descriptive	Range
Yawning	83.34%	-
Change position frequently	58.73%	-
Frequent eye blinks	51.40%	-
Difficulty concentrating on driving	50.59%	-
Slower reaction to traffic events	39.78%	-
Increased variation in speed	38.60%	-
Difficulty keeping eyes open	35.11%	-
Dreamlike state of consciousness	24.11%	-
Total signs of sleepiness[a]	4.12 ± 2.10	1-8
Hours driving per week (>8hrs)	35.74%	-
Age	37.66 ± 17.65	17-90
Sex (male)	50.03%	
Education level (tertiary level)	36.36%	-
Professional driver (yes)	13.66%	-
Shift worker (yes)	12.49%	-
Continued driving while sleepy (yes)	65.88%	-
Ever had a sleep-related close call (yes)	15.79%	-
Difficulty getting to sleep (yes)	37.04%	-
Hours of sleep per night	7.29 ± 1.17	4-10
Quality of normal sleep	2.56 ± 0.82	1-4
Frequent daytime sleepiness (yes)	16.22%	-

[a] Total signs of sleepiness variable was the summation of the eight specific signs of sleepiness

Hierarchical multiple regression was performed to examine which of the demographic, work, and sleep-related variables were associated with the total signs of sleepiness outcome variable and can been seen in Table 2 (over page). At the first step, hours driving per week was entered into the model, which significantly predicted signs of sleepiness and accounted for 1% of the variance. At the second step the demographic variables were included into the model, which significantly predicted signs of sleepiness and accounted for 5% of the variance, an increase of 4%. Hours driving per week, age, and education were all significantly associated with signs of sleepiness. The last step saw the remaining work and sleep-related variables entered into the model, which significantly predicted signs of sleepiness and accounted for 31% of the variance, an increase of 26%. Of the variables that were entered at the third step, being a professional driver, continue to drive when sleepy, sleep-related close call, hours of sleep per night, quality of sleep, and experiencing frequent daytime sleepiness were significantly associated with the outcome variable sign of sleepiness. The variables with the largest associations with the signs of sleepiness outcome variable were continuing to drive when sleepy, followed by sleep-related close call, and hours of sleep per night.

Table 2. Hierarchical multiple regression analysis of total signs of sleepiness and the demographic, work and sleep-related variables

Study variable	*b*	*SE b*	β	$r_{ab.c}$	$r_{a(bc)}$
Step 1					
Hours driving per week (>8hrs)	**0.25^{*}**	**.11**	**.06**	**.06**	**.06**
Constant	**3.73^{**}**	**.07**			
Adjusted $R^2 = .01$; $F(1, 1595) = 5.01^{*}$					
Step 2					
Hours driving per week (>8hrs)	**0.28^{*}**	**.11**	**.06**	**.06**	**.06**
Age	**-0.02^{**}**	**.01**	**-.19**	**-.19**	**-.19**
Sex (male)	-0.09	.10	-.02	-.02	-.02
Education (tertiary level)	**0.58^{**}**	**.11**	**.13**	**.13**	**.13**
Constant	**4.42^{**}**	**.14**			
Adjusted $R^2 = .05$; $F(4, 1592) = 22.47^{**}$; R^2 change = .04; $F_{change}(3, 1592) = 28.20^{**}$					
Step 3					
Hours driving per week (>8hrs)	0.08	.10	.02	.02	.02
Age	**-0.01^{**}**	**.01**	**-.09**	**-.10**	**-.09**
Sex (male)	**-0.31^{**}**	**.09**	**-.07**	**-.09**	**-.07**
Education (tertiary level)	**0.39^{**}**	**.09**	**.09**	**.11**	**.09**
Professional driver (yes)	**0.22^{*}**	**.10**	**.05**	**.06**	**.05**
Shift worker (yes)	0.09	.14	.01	.02	.01
Continue to drive when sleepy (yes)	**1.66^{**}**	**.10**	**.37**	**.39**	**.35**
Sleep-related close call (yes)	**1.36^{**}**	**.12**	**.24**	**.27**	**.23**
Difficulty getting to sleep (yes)	0.01	.11	.01	.01	.01
Hours of sleep per night	**-0.17^{**}**	**.04**	**-.09**	**-.10**	**-.09**
Quality of normal sleep	**-0.13^{*}**	**.07**	**-.05**	**-.05**	**-.04**
Frequent daytime sleepiness (yes)	**0.28^{**}**	**.13**	**.05**	**.06**	**.05**
Constant	**3.75^{**}**	**.28**			
Adjusted $R^2 = .31$; $F(12, 1584) = 61.22^{**}$; R^2 change = .26; $F_{change}(8, 1584) = 77.13^{**}$					

$^{**}p < .01$, $^{*}p < .05$

Signs of Sleepiness and Risky Sleepy Driving Behaviours

Continuing to drive when sleepy was significantly associated with sleep-related close call ($B = 1.24$, $p < .001$). Similarly, continuing to drive when sleepy was significantly associated with signs of sleepiness ($B = 2.07$, $p < .001$). Signs of sleepiness was significantly associated with sleep-related close calls ($B = 0.48$, $p < .001$). A significant association was found between signs of sleepiness and sleep-related close calls when controlling for the association of continuing to drive when sleepy, $B = 0.45$, $p < .001$. The relationship between continuing to drive when sleepy and sleep-related close calls decreased to $B = 0.49$, $p = .014$. The significance of the indirect pathway was evaluated with a bootstrapping procedure (Hayes, 2013). The bootstrapping range (2000 bootstrap resamples) with 95% bias corrected for the signs of sleepiness variable was, 0.74 to 1.11. Overall, the mediator model (see Figure 1) accounted for 18.53% of the variance (Nagelkerke R^2).

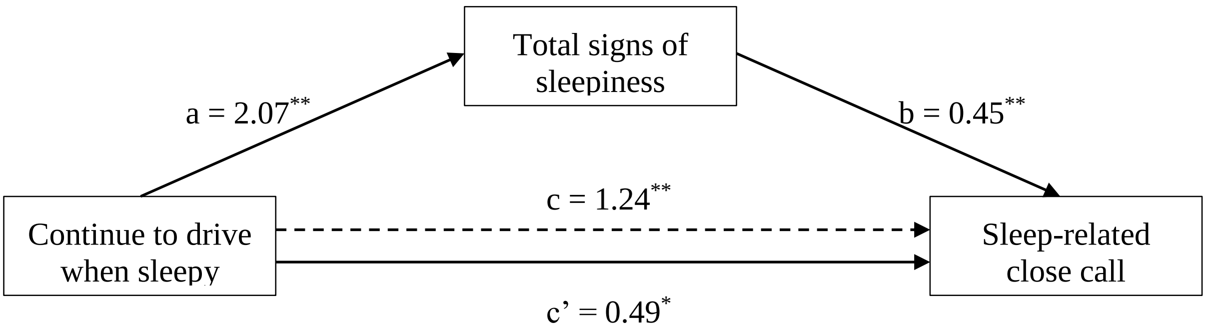

Figure 1. Mediation model of Continue to drive when sleepy with sleep-related close call as mediated by signs of sleepiness – unstandardised coefficients shown. $^{**}p < .01$, $^{*}p < .05$

Subgroup Analyses

A number of significant differences were found between the younger age group (17-29 years of age) and the older group (> 30 years of age) and can be seen in Table 3. The younger group were more likely to report continuing to drive when sleepy as well as experience more of the signs of sleepiness. Males were more likely to report having more sleep-related close calls and to continue to drive when sleepy than females.

Table 3. Age and sex comparisons for the sleepy driving variables

Variable	Age		Statistical comparison	Sex		Statistical comparison
	17-29	> 30		Female	Male	
Sleep-related close calls	14.63%	16.93%	$\chi^2(1) = 1.61$	**11.94%**	**19.63%**	$\boldsymbol{\chi^2(1) = 17.88^{**}}$
Continue to drive when sleepy	**74.25%**	**57.60%**	$\boldsymbol{\chi^2(1) = 49.60^{**}}$	**39.44%**	**62.31%**	$\boldsymbol{\chi^2(1) = 9.09^{**}}$
Total signs of sleepiness	$\boldsymbol{M = 4.04}$	$\boldsymbol{M = 3.85}$	$\boldsymbol{U = 294628.50^{**}}$	$M = 4.05$	$M = 3.99$	$U = 318059.00$

Note: $^{**}p < .01$, $^{*}p < .05$; χ^2 denotes chi-squared statistic; U denotes the Mann-Whitney statistic.

Discussion

The current study sought to examine the relationships between drivers' experiences of the signs of sleepiness, risky sleepy driving behaviours, and the associations with demographic, work and sleep-related factors. The results reveal that a number of demographic, work and sleep-related factors were associated with experiencing signs of sleepiness while driving. Moreover, the signs of sleepiness were also associated with certain sleepy driving behaviours.

The study results suggest that participants had considerable experience with many signs of sleepiness. It was found that over half of the participants reported having previously experienced four of the eight signs of sleepiness. These included: Yawning, changing position frequently, frequent eye blink, and difficulty concentrating on driving. These particular signs of sleepiness could be described as early signs and experienced during initial development of sleepiness. It is notable that the earlier signs of sleepiness (e.g., yawning, changing position frequently) were reported as having been experienced the most, with the more advanced signs of sleepiness (e.g., difficulty keeping eyes open, dreamlike state of consciousness) experienced less – this pattern of experiencing the signs of sleepiness is consistent with previous research (Kaplan et al., 2007; Nordbakke & Sagberg, 2007). Nonetheless, it is concerning that approximately a third of participants had previously experienced two of the more advanced signs of sleepiness such as keeping eyes open and dreamlike state of consciousness. Simulator studies demonstrate that "struggling to keep your eyes open" had the strongest relationship with impaired driving performance (Howard et al., 2014). Moreover, difficulties keeping eyes open could be considered an eight or a nine on the widely used Karolinska Sleepiness Scale (KSS: Åkerstedt & Gillberg, 1990). Biomathematical modelling with retrospective crash data has determined that scoring an 8 or 9 on the KSS is associated with a 7 to 9 times increase in the likelihood of crashing when driving a motor vehicle (Åkerstedt, Connor, Gray, & Kecklund, 2008).

The first aim of the study was to examine the association between demographic, work-, and sleep-related variables with the signs of sleepiness. A number of demographic, work and sleep-related factors were associated with experiencing signs of sleepiness while driving with the hierarchical regression analysis. At the final step of the regression the demographic and work-related factors of age (being younger), sex (being female), having a tertiary level of education, and being a professional driver were associated with having experienced more of the signs of sleepiness. Previous research demonstrates that younger drivers (Nordbakke & Sagberg, 2007) and professional drivers (Carter et al., 2003) frequently drive while sleepy and this would likely predispose them to experiencing more of the signs of sleepiness. It was somewhat unexpected that females were more likely to be associated with experiencing signs of sleepiness than males as previous research has shown that males, compared to females, are more likely to report driving when sleepy (Radun et al., 2015). Nordbakke and Sagberg (2007) determined that signs of sleepiness such as “feeling cold” and “increased variations in speed” were experienced more by female drivers, but overall, few differences were evident between males and females. The association between having a tertiary education and experiencing more signs of sleepiness is a novel finding. Previous research has demonstrated an association between higher education levels and greater likelihood of being involved in a sleep-related crash (Sagberg, 1999) and individuals with higher education levels are more likely to report shorter sleeping durations (Lauderdale et al., 2006) and thus might have a greater sleep debt which could increase general levels of sleepiness.

Perhaps the most straightforward findings are the sleep-related factors associated with signs of sleepiness. The variables of hours of sleep per night (fewer hours), quality of normal sleep (poor quality), and experiencing frequent daytime sleepiness were all related to experiencing more signs of sleepiness. These findings are consistent with previous research (Connor et al., 2002; Radun et al., 2015) and further support the importance of sleep health as a protective factor for negating sleepiness while driving. It must be noted that while the magnitude of the associations between the sleep-related factors and experiencing signs of sleepiness were small, they were still significant after controlling for a number of demographic factors and sleepy driving behaviours.

Two-thirds of the participants reported having previously continued driving while sleepy in the past. This finding is consistent with previous research conducted on representative samples in Norway (Nordbakke & Sagberg, 2007) and Canada (Vanlaar, Simpson, Mayhew, & Robertson, 2008) that documented between 59 and 73 percent of drivers report that they would continue to drive despite being aware of their sleepiness. The percentage of drivers reported having a previous close call in the current study was 16%. This percentage is consistent with a large North American study that found 18% of its 35,217 drivers reported having had a close call previously (Powell et al., 2007). These two sleep-related driving variables had the strongest associations with experiencing more signs of sleepiness. These relationships were further examined with a mediation analysis.

The second aim was to examine the relationships between signs of driver sleepiness, continuing to drive when sleepy and sleep-related close calls. The current data supported a mediation model of these variables. Specifically, drivers who had previously continued driving while sleepy were more likely to also report having a sleep-related close call, with this relationship partially mediated by having experienced more signs of sleepiness. Increasing experiences of the numbers of signs of sleepiness are associated with microsleeps (Kaplan et al., 2007) and with greater levels of impaired simulated driving (Howard et al., 2014). This mediation model emphasises the importance a driver should take with their experiences of the signs of sleepiness. Last, the dangerousness of having a close call has been demonstrated by Powell et al. (2007) with drivers who have previously had one close call being 1.13 times more likely to have a sleep-related crash.

In the absence of a reliable and more importantly, a valid technological device that can measure a driver’s level of sleepiness, drivers are reliant on self-awareness of experiencing the signs of sleepiness as a guide to their level of impairment. A growing body of literature is demonstrating that drivers’ can perceive increasing levels of sleepiness (Reyner & Horne, 1998; Watling, Smith, & Horswill, 2015; Williamson, Friswell, Olivier, & Grzebieta, 2014). Yet, with such large proportions of drivers choosing to drive while sleepy or to continue to drive while sleepy, it seems likely that several factors could affect drivers’ decision making. For instance, motivations as well as risk perceptions are important factors associated with continuing to drive while sleepy (Watling, Armstrong, Obst, & Smith, 2014). Moreover, some drivers might also overestimate how effectual fighting sleepiness actually can be. This sentiment is supported by research demonstrating that the accuracy of predicting the likelihood of falling asleep is poor when experiencing an advanced level of sleepiness, such as when sleep onset is being actively fought (Kaplan et al., 2007). However, at such levels of sleepiness it has been suggested that an individual is well past the point of impairment from sleepiness (Kribbs & Dinges, 1994) and thus, taking prompt action and employing the more effective countermeasures (i.e., naps, coffee) is of critical importance for road safety.

The third aim sought to determine differences between younger (17-29 years of age) and older (> 30 years of age) individuals as well as between females and males. This subgroup analysis of younger and older drivers, found younger drivers were more likely to continue to drive when sleepy, despite experiencing more signs of sleepiness. A simulated driving study performed by (Sagberg, Jackson, Krüger, Muzet, & Williams, 2004) also revealed that younger drivers reported more signs of sleepiness than older drivers. This finding is somewhat counterintuitive as older drivers have more accumulated experiences with sleepy driving than younger drivers. Although, it could be that younger persons *feel* the signs of sleepiness more *strongly;* previous research suggests that younger drivers display higher levels of physiological sleepiness than older drivers do (Lowden, Anund, Kecklund, Peters, & Åkerstedt, 2009).

The subgroup analysis also found females were significantly less likely than males to report having a sleep-related close call as well as to continue driving while sleepy; yet, surprisingly no differences between females and males with the total signs of sleepiness variable were found. Thus, it is likely that other factors such as sensation seeking, impulsivity, and risk taking could have contributed to males performing these risky sleepy driving behaviours more than females. Alternatively, while no differences were found between males and females and their previous experiences with the signs of sleepiness, it could be that females appreciate the dangerousness of the signs of sleepiness to a greater extent than males and as a consequence, perform less risky sleepy driving behaviours than males when they do experience the signs of sleepiness.

Moving forward together, driver informational resources, educational campaigns as well as police and community discussion groups could seek to educate drivers about the importance of first, being more cognizant of experiences of the signs of sleepiness when driving, and second, being more conscientious that experiencing more signs of sleepiness when driving indicates an increasing of ones level of sleepiness. Moreover, sleepiness knows no boundaries, such that sleepiness is not just a road safety issue that is solely localised within rural driving environments, but occurs in urban driving environments as well (e.g., Armstrong, Smith, Steinhardt, & Haworth, 2008). Longitudinal epidemiological evidence demonstrates that sleep health is gradually declining (Bixler, 2009) and messages that highlight the importance of sleep health as a protective factor are still important as the current study has shown that several sleep health factors were related to experiencing signs of sleepiness. It is acknowledged that individual’s sleep health will, from time-to-time be poor, the individual then needs to have a heightened appreciation of the risk of driving while sleepy.

There are a number of limitations of the study that need to be considered. The data was collected via self-report. Thus, social desirability and recall bias could have affected the results. Given the retrospective and cross-sectional nature of the study design, causality of the obtained relationships cannot be inferred. Future research could seek to explore the effect of age as younger drivers reported experiencing more signs of sleepiness. Previous research has shown certain individuals report fewer signs of sleepiness when at heightened levels of sleepiness (i.e., Kaplan et al., 2007). The basis of this effect should be explored in a driving setting to determine if it is an awareness level or whether it could be associated with a psychological construct (i.e., personality factors).

In conclusion, the current study demonstrated that drivers have substantial experience with the signs of sleepiness. Moreover, a number of demographic, work and sleep-related factors were associated with experiencing signs of sleepiness when driving. In particular, continuing to drive while sleepy and having a sleep related close call had the strongest associations with the signs of sleepiness. Additionally, signs of sleepiness were also found to mediate the relationship between continuing to drive while sleepy and having a sleep-related close call event. Working together to educate all drivers about the dangerousness of driving while sleepy is an important undertaking, which could lead to improvements in road safety outcomes and provide a safer road environment for all drivers.

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Sleepy driving and drink driving: attitudes, behaviours, and perceived legitimacy of enforcement of younger and older drivers

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Abstract

Sleepy driving and drink driving are two risky driving behaviours that substantially contribute to road crashes. Several studies demonstrate equivalent levels of impairment from both sleepy and drink driving. Yet, drivers perceive sleepy and drink driving distinctly different, with younger and older drivers engaging in these two risky driving behaviours at different rates. The current study sought to examine the sleepy and drink driving behaviours and perceptions in a sample of 114 younger (17-29 years) and 177 older (30+ years) drivers. Compared to older drivers, younger drivers reported more positive attitudes toward sleepy and drink driving behaviours, as well as more negative views regarding perceived legitimacy of sleepy driving enforcement. Younger drivers were also more likely to report performing sleepy driving behaviours than older drivers. Younger drivers reported greater likelihood to drive while sleepy, lower perceptions of legitimacy for sleepy driving, and more positive attitudes towards sleepy driving when compared to drink driving and the same pattern was found for older drivers as well. Subsequently, the self-reported likelihood of driving while sleepy was greater than drink driving in both age groups. Overall, the results suggest that sleepy driving is not viewed as equally dangerous as drink driving with younger drivers' perceptions being more lenient than older drivers' perceptions. It is likely that change is needed regarding the perceptions of dangerousness of sleepy driving with a particular focus on younger drivers seemingly needed.

Introduction

Sleepy driving and drink driving are two risky driving behaviours that contribute substantially to crash incidents. In Queensland, 20% of the state's fatal crashes were attributed to drink driving (Department Transport and Main Roads [DTMR], 2012). The contribution of sleepy driving (also described as fatigued driving) to the state's fatal crash incidents has been estimated to be 15% (DTMR, 2012), although accurate incidence rates for sleep-related crashes are difficult to ascertain. This is in part due to the absence of an objective test for measuring a driver's sleepiness level, either before or after a crash. The current best estimate of the involvement of sleepiness in crashes comes from a stringent population based case-control study performed in New Zealand, where 19% of all fatal and severe crashes were attributed to sleepiness (Connor et al., 2002). In addition, most crashes are multifactorial in nature and sleepiness might have substantially contributed to crashes primarily attributed to other factors such as alcohol or speeding (Watling, Armstrong, & Smith, 2013). Consequently, the true incidence rates of sleep-related crashes are likely higher than any obtained rates (Åkerstedt, 2000; Cercarelli & Haworth, 2002).

The Impact of Alcohol and Sleepiness on Driving Performance

The performance decrements from alcohol intoxication and from sleepiness are substantial. Laboratory based cognitive and psychomotor studies demonstrate alcohol intoxication produces a dose-related impairment on a number of psychological tasks critical to driving including, attention, working memory, psychomotor performance, motor control/coordination, planning, and tracking (Fogarty & Vogel-Sprott, 2002; Hindmarch, Kerr, & Sherwood, 1991; Peterson, Rothfleisch, Zelazo, & Pihl, 1990). These impairments can also persist during the hangover period which can last up to 12 hours after the alcohol has left the body (McKinney & Coyle, 2004; Prat, Adan, Perez-

Pamies, & Sanchez-Turet, 2008). Similarly, sleepiness produces impairments on attention, working memory, psychomotor performance, and tracking (Dawson & Reid, 1997; Van Dongen, Maislin, Mullington, & Dinges, 2003; Williamson & Feyer, 2000). The impairments from sleepiness are dose-related, such that greater impairments are observed with the longer the duration of wakefulness (Williamson & Feyer, 2000) or the greater the number of nights of partial sleep deprivation (Van Dongen et al., 2003). Cognitive recovery from complete sleep deprivation or disturbed circadian rhythmicity can take between two to five days (Åkerstedt, Kecklund, Gillberg, Lowden, & Axelsson, 2000; Ikegami et al., 2009).

The impairments associated with alcohol intoxication as well as sleepiness have also been demonstrated in simulated driving studies. The association between alcohol intoxication and decrements of lane positioning stability, speed control, and braking times, as well as increased collision frequency has been found (Howland et al., 2011; Ramaekers, Robbe, & O'Hanlon, 2000). Similarly, sleepiness is associated with decrements of simulated driving lane positioning, speed control, and near misses (Arnedt, Wilde, Munt, & MacLean, 2001; Gillberg, Kecklund, & Åkerstedt, 1996). Moreover, alcohol intoxication and sleepiness do not only impact on simulated driving performance, but also on risk acceptability and decision making in relation to driving. Studies have demonstrated that decision making is impaired and the acceptability of risk increases with alcohol intoxication (Lane, Cherek, Pietras, & Tcheremissine, 2004) and sleepiness (Rossa, Smith, Allan, & Sullivan, 2014).

On-road impairment to driving ability has been demonstrated through a robust relationship between blood alcohol content (BAC) levels and actual crash likelihood. The seminal Grand Rapids study (Borkenstein, Crowther, Shumate, Zeil, & Zylman, 1964) and a more recent study by Blomberg, Peck, Moskowitz, Burns, and Fiorentino (2009) have demonstrated that driving impairment occurs at a BAC of approximately 0.04%. Thereafter, crash risk continues to increase as BAC levels increase – such that, relative to a BAC of < 0.05%, BACs of 0.05-0.08% and ≥ 0.08% have been associated with a five and 15 times greater crash propensity (Movig et al., 2004). Regarding the crash risk associated with sleepiness, Åkerstedt, Connor, Gray, and Kecklund (2008) performed an analysis on retrospective crash data with biomathematical modelling of the drivers levels of sleepiness based on the validated Karolinska Sleepiness Scale (KSS: Åkerstedt & Gillberg, 1990) a 9-point Likert scale, with higher scores indicting greater sleepiness. Overall, the odds of having a sleep-related crash rapidly increase in a non-linear, almost exponential curve as subjective sleepiness levels increases. Specifically, relative to a KSS of three (alert), a KSS of six (some signs of sleepiness) and a KSS of eight (sleepy, some effort to stay awake) were associated with a three and seven times greater likelihood of crashing respectively. Considered together, driving while intoxicated and driving while sleepy both result in substantial increases to crash risk.

Comparing the Effect of Alcohol and Sleepiness

Laboratory based comparisons between the impact of alcohol intoxication and sleepiness on performance have demonstrated that moderate levels of extended wakefulness (17 hours) and alcohol intoxication (0.05% BAC) result in approximately equivalent performance decrement on a number of cognitive and psychomotor tasks, including, unstable tracking, vigilance, spatial memory, symbol digit coding (Dawson & Reid, 1997; Williamson & Feyer, 2000). When the duration of wakefulness reaches 20 hours, the performances decrement is equivalent to having a BAC of 0.1% (Dawson & Reid, 1997; Williamson & Feyer, 2000). Similarly, performance decrements have been noted in driving simulator studies, such that 18.5 hours and 21 hours of wakefulness has been equated to driving performance decrements associated with BAC levels of 0.05% and 0.08% respectively (Arnedt et al., 2001). Considered together, the results from these studies suggest that the level of performance decrement associated with 17 hours of extended wakefulness approaches the decrement associated with the legal BAC limit for driving in Australia, New Zealand, and many other countries.

Drink Driving and Sleepy Driving Attitudes

While both sleepy and drink driving are associated with comparable decrements of driving performance and increased crash likelihood, the risk perception of these two driving behaviours is somewhat disparate. For instance, several studies reveal that sleepy driving is typically rated less critical than other risky driving behaviours such as speeding or drink driving by drivers (Pennay, 2008; Radun, Radun, Wahde, Watling, & Kecklund, 2015). In Australia, sustained policing activity and media campaigns rolled out over several decades have changed community attitudes and increased social disapproval of drink driving (Homel, 1988). However, during this time little change in community attitudes towards sleepy driving has occurred (Fletcher, McCulloch, Baulk, & Dawson, 2005). While few studies have directly compared drink and sleepy driving attitudes, perceptions of culpability have been found to be higher for drink drivers who involved in a crash, than those that are involved in a sleep-related crash (Williams, Davies, Thiele, Davidson, & MacLean, 2012). Considering the perceptions of culpability associated with sleepy driving and drink driving it is likely that perceived legitimacy of enforcement for drink driving would be more positive than sleepy driving.

Differences between Younger and Older Drivers

In addition to differences in attitudes toward drink driving and sleepy driving, the literature indicates that pronounced differences exists between age-cohorts. Typically, younger drivers hold lower risk perception of crashing for both drink driving (Jewell, Hupp, & Segrist, 2008) and sleepy driving (Watling, Armstrong, Obst, & Smith, 2014) when compared to older drivers and hold more negative views towards traffic law enforcement in general (Bates, Darvell, & Watson, 2015; Scott-Parker, Watson, King, & Hyde, 2012). Lower risk perception for crashing and negative attitudes toward traffic enforcement and can lead to engagement of risky driving behaviours (Rhodes & Pivik, 2011; Scott-Parker et al., 2012). Indeed, studies have demonstrated that younger drivers are more likely to drive while sleepy (Watling et al., 2014) or intoxicated (World Health Organization, 2013) than older drivers. While younger drivers report lower crash risk perceptions for drink driving as well as driving while sleepy than older drivers, it is not known whether attitudes as well as the perceived legitimacy of enforcement for drink driving and sleepy driving differ between younger and older drivers.

The Current Study

Crashes attributed to drink driving and sleepy driving account for a substantial proportion of road crashes. While equivalent impairment levels associated with drink driving and sleepy driving have been demonstrated, some studies suggest drink driving and sleepy driving could be perceived differently by younger and older drivers. The current study sought to examine the driving behaviour likelihood, perceived legitimacy of traffic law enforcement, and attitudes for drink driving and sleepy driving in a sample of 114 younger (17-29 years) and 177 older (30+ years) drivers.

Method

Participants

To be eligible for participation in this study, individuals were required to drive on Queensland roads and hold an Open driver's licence. In total, 291 participants' (females: 59%, males: 41%) responses were collected in the study. In total, there were 114 younger drivers (17-29 years) and 177 older drivers (30+ years). The characteristics of the younger and older drivers can be seen in Table 1.

Table 1. Demographics and traffic-related information of the younger and older drivers.

Variable	Younger	Older
Age (years)	24.46 (2.77)	48.63 (11.56)
Sex		
Female	66.67%	54.85%
Male	33.33%	45.15%
Education		
Primary	-	0.56%
Secondary	16.67%	18.08%
TAFE or Trade apprenticeship	21.93%	24.29%
University	61.40%	57.07%
Employment		
Employed (full-time)	60.53%	55.93%
Employed (part-time or casual)	19.30%	19.21%
Self-employed	3.51%	13.56%
Student	15.78%	5.08%
Unemployed	0.88%	6.22%
Hours per week driving		
0-10 hours	66.67%	57.95%
11-20 hours	28.95%	35.80%
21+ hours	4.38%	6.25%
Note: Mean value displayed before brackets, standard deviation displayed inside brackets		

Measures

Demographic (age, sex, education, and employment status) and traffic-related information (hours spent driving per week) were obtained from the participants. The self-reported likelihood of sleepy driving and drink driving in the next month was assessed via two items and three items, respectively. The sleepy driving items examined the likelihood of sleepy driving when alone or with passengers. The drink driving items assessed drink driving likelihood in three contexts; when driving in the late/early morning hours, when driving alone, and when driving with passengers. All items were measured on a 5-point Likert scale ranging from 1 (extremely unlikely) to 5 (extremely likely). The items measuring each construct were averaged to create two scale scores.

Enforcement of sleepy driving is typically not preventative, but rather occurs after a crash has taken place; thus, the perceived legitimacy of *reactive* enforcement was assessed. Participants were asked to indicated their agreement with three statements, measured on a 5-point Likert scale scored 1 (strongly disagree) to 5 (strongly agree). One example item was; “It is fair to charge someone if they crash due to sleepiness”. Perceived legitimacy of drink driving enforcement was assessed with four items, scored on the same 5-point Likert scale. The items assessed both fairness of random breath testing (e.g., “It is fair to enforce drink driving laws by randomly breath testing drivers”) and of mandatory breath testing of drivers involved in crashes and of targeting drivers with erratic driving patterns (e.g., “It is fair to enforce drink driving laws by breath testing all drivers in a crash”). Scale scores were created by averaging items measuring the two driving behaviours.

The definitions components (i.e., attitudes) of Akers, Krohn, Lanza-Kaduce, and Radosevich (1979) social learning theory were utilised to measure the driving behaviour attitudes. Following Aker’s lead, two positive, two negative, and two neutral items for each of the driving behaviours were included. Examples of items were: “People who drive when they think they are sleepy are generally more careful on the road” (sleepy driving, positive), “It’s okay to drive when you think you might be over the legal alcohol limit, as long as no one gets hurt” (drink driving, neutral), and “there is no excuse for sleepy driving” (sleepy driving, negative). All items were measured on a 5-point Likert scale from 1 (strongly disagree) to 5 (strongly agree). After reverse scoring the negative items, two attitudinal scale scores were created by averaging the six items for each driving behaviour.

Procedure

After the study's protocol received approval from the University's Human Research Ethics Committee as well as health and safety approval, the data collection commenced. Potential participants were invited to take part in the study via the university's email distribution lists, participation webpages, and through social networking sites. Participants were offered the chance to enter a random draw for one of six $50 petrol vouchers as an incentive for their participation. The online survey remained open for approximately one month. It was not possible to complete the survey more than once using the same Internet Protocol (IP) address. The data was cleaned and assumptions of the included statistical tests were checked before the final analysis was performed.

Statistical Analyses

The proportions of females and males was significantly different between the younger and older drivers age groups ($\chi^2(1, 291) = 4.43$, $p = .04$) – this difference has the potential to confound the results as males report greater frequency of drink driving (Pennay, 2008; World Health Organization, 2013) as well as sleepy driving than females (Radun et al., 2015; Watling et al., 2014). Thus, attempting to control for these sex differences, a multivariate analysis of covariance was performed on the dependant variables (i.e., driving behaviour likelihood, perceived legitimacy of enforcement, and attitudes for drink driving and sleepy driving), the independent variable was age group (i.e., younger and older drivers), and sex was the covariate. The second analysis sought to examine the within age group comparisons between drink driving and sleepy driving and thus, a series of paired-samples *t*-tests were performed on driving behaviour likelihood, perceived legitimacy of enforcement, and attitudes variables. Sex was not controlled with these analyses for as the proportions of females and males did not change across the comparisons within the age groups.

Results

Table 2 displays the means, standard deviations and age group comparisons as well within age group comparisons. The covariate, sex, was significantly related to the dependant variables (Wilks' $\Lambda = 0.95$, $F(6, 281) = 2.64$, $p = .02$, partial $\eta^2 = .05$). A significant multivariate analysis of covariance effect of age group was found between younger and older drivers (Wilks' $\Lambda = 0.90$, $F(6, 281) = 4.96$, $p < .001$, partial $\eta^2 = .10$) after controlling for sex. Univariate tests comparing age groups differences and interpreted with the Bonferroni correction, found younger drivers reported greater likelihood to drive while sleepy than older drivers, reported more positive attitudes for sleepy and drink driving behaviours, and more negative views for perceived legitimacy of enforcement for sleepy driving. Comparing the younger drivers drink driving behaviours and perceptions to the sleepy driving, younger drivers reported greater likelihood to drive while sleepy, greater perceptions of legitimacy for drink driving, and more positive attitudes towards sleepy driving. The same pattern was found for the older drivers.

Table 2. Means, standard deviations, and comparisons for the study variables

	Drivers' age group		**Comparisons**		
	Younger	**Older**	**Younger-older**	**Younger: DD-SlpD**	**Older: DD-SlpD**
Variable	***M* (*SD*)**	***M* (*SD*)**	***F*-test**	***t*-test**	***t*-test**
Drink driving behaviour likelihood	1.33 (0.60)	1.26 (0.63)	1.65	-15.19^{**}	-11.76^{**}
Sleepy driving behaviour likelihood	2.84 (1.05)	2.34 (1.19)	14.26^{**}		
Drink driving perceived legitimacy	4.36 (0.53)	4.51 (0.51)	6.02	12.72^{**}	14.82^{**}
Sleepy driving perceived legitimacy	3.22 (0.84)	3.62 (0.82)	16.29^{**}		
Drink driving attitudes	1.77 (0.65)	1.57 (0.49)	10.57^{**}	-12.87^{**}	-13.09^{**}
Sleepy driving attitudes	2.27 (0.72)	2.01 (0.65)	11.49^{**}		

Note: *M*, mean value; *SD*, standard deviation; DD-SlpD, drink driving compared to sleepy driving.
$^{*} < .05$, $^{**} < .01$

Discussion

The current study sought to compare the driving behaviours and perceptions of drink driving and sleepy driving, among younger and older drivers. Although comparable decrements in driving ability and increased crash-risk for these driving behaviours have been demonstrated (Åkerstedt et al., 2008; Blomberg et al., 2009), previous research indicates that attitudes toward sleepy driving are more lenient than those held toward drink driving (Pennay, 2008; Radun et al., 2015). This finding was supported in the current study, with both younger and older drivers reporting more positive attitudes toward sleepy driving. Additionally, both younger and older drivers report a higher likelihood of future sleepy driving and lower levels of perceived legitimacy of reactive enforcement targeting this driving behaviour. These results are of interest as they further highlight important differences between two driving behaviours that are responsible for a considerable proportion of road trauma (Connor et al., 2002; DTMR, 2012).

Several explanations for the differences between drink and sleepy driving behaviours and perceptions can be proposed. Previous literature demonstrates that greater culpability is typically ascribed to crash-involved drivers who were under the influence of alcohol at the time of the crash compared to those who were sleepy (Williams et al., 2012). Together with the findings of the current study (more positive attitudes towards sleepy driving and lower perceived legitimacy of enforcement) results such as those by Williams et al. (2012) indicate that sleepy driving is, overall, seen as less dangerous. Indeed, surveys of drivers demonstrate that sleepy driving is typically rated lower as a critical crash risk factor than drink driving (Radun et al., 2015; Vanlaar, Simpson, Mayhew, & Robertson, 2008). The current results likely reflect efforts of sustained drink driving enforcement and community education campaigns that have changed social norms of the acceptability of drink driving.

The engagement in the two driving behaviours is not only influenced by attitudes and perceptions of legitimacy (e.g., Watling & Leal, 2012), but also by the several other factors (i.e., differences in enforcement and public education) as well the personal choice to drive under these conditions. Largely, drinking alcohol and then choosing to drive while intoxicated is a volitional behaviour. Moreover, alcohol consumption might occur relatively infrequent and in situations when alternative modes of transportation are an available and feasible option. Whereas, experiencing sleepiness is not always a volitional choice; there are a number of factors (e.g., undiagnosed sleep disorder, parenthood, illness, being a shift worker), that are difficult for individuals to control, that can affect the quality and/or quantity of sleep obtained (Åkerstedt, 2000; Alonderis et al., 2008). Moreover, sleepiness, particularly that of a chronic nature, often occurs during ordinary day-to-day driving which makes the use of alternative modes of transport impractical. This difference between intoxication and sleepiness might play a role in the formation of attitudes among drivers.

As stated earlier, choosing to experience sleepiness is not always volitional; choosing to continue to drive while aware of an increasing level of sleepy is, however, a volitional behaviour. Surveys of drivers suggest that continuing to drive while sleepy is a behaviour performed by a substantial proportion of drivers (i.e., 57-73%: Nordbakke & Sagberg, 2007; Vanlaar et al., 2008). Moreover, an increasing body of literature demonstrates that drivers can perceive increasing levels of sleepiness (Reyner & Horne, 1998; Watling, Smith, & Horswill, 2015; Williamson, Friswell, Olivier, & Grzebieta, 2014) and drivers are also cognizant of pre-trip factors that can lead to experiencing sleepiness while driving (Radun et al., 2015). Thus, differences in the volitional control over sleepy and drink driving should not detract from drivers' personal responsibility to ensure that their sleepy driving behaviours do not jeopardise their own safety and that of other road users.

In terms of age-differences, and in line with previous research (e.g., Radun et al., 2015; Watling et al., 2014), it was also found that younger drivers were more likely to drive when sleepy than older drivers. Moreover, the present study found that young drivers have more favourable attitudes toward sleepy driving and lower perceived legitimacy of enforcement of sleepy driving. Thus, while sleepy driving was overall more acceptable among participants of both age groups, this was most pronounced among the young drivers. These findings could be understood, first, in relation to the lower levels of sleepy driving risk perception that has previously been found among younger drivers (Watling et al., 2014); lower levels of perceived dangerousness likely leads to more accepting attitudes (Lucidi et al., 2006). The obtained findings regarding the younger drivers' perceptions of legitimacy in the current study are also in line with previous research that demonstrates younger drivers, hold more negative views towards traffic law enforcement in general (Bates et al., 2015; Scott-Parker et al., 2012). Last, attitudes and perceptions towards driving are likely shaped during early driving experiences. Younger drivers who drive while sleepy might not yet have experienced any negative outcomes are therefore likely to have more positive views of driving while sleepy (Lucidi et al., 2006). Consequently, as drivers gain more negative experiences with sleepy driving (i.e., sleep-related close calls, sleep-related crashes) they then come to appreciate the dangerous associated with sleepy driving.

It was found that younger drivers held more positive attitudes towards drink driving than older drivers. The lack of significant differences between younger and older drivers for the drink driving likelihood and perceptions of legitimacy of enforcement for drink driving was therefore unexpected and moreover inconsistent with previous research (e.g., World Health Organization, 2013). While younger drivers, overall, hold more negative attitudes toward traffic enforcement (Bates et al., 2015; Scott-Parker et al., 2012), this was not reflected in terms of drink driving in the current study. Perhaps the strong emphasis of sustained drink driving enforcement and media campaigns regarding the dangerousness of drink driving, whereby drinking and driving is perceived contrary to social norms has resulted in a homogenisation across age groups.

When considering the study findings, the limitations of the current study should be kept in mind. One limitation of the study was the sampling methodology. A convenience sample was used which might result in self-selection bias. Moreover, the use of self-report measures for this study leaves it susceptible to self-reporting bias and might not be reflective of participants' actual behavioural likelihood and perceptions of driving while intoxicated or while sleepy. Finally, the cross-sectional design does not allow for inferences of causality to be made from the obtained results. Future research could seek to perform more in-depth analyses of drink driving and sleepy driving behaviours and particularly the attitudes and perceptions of drivers concerning these behaviours. Several suggestions have been given above regarding the reasons behind sleepy driving and drink driving differences. However, in order to design effective intervention campaigns, such assumptions need to be formally tested. For instance, if the pervasive and the somewhat non-volitional nature of sleepiness are indeed linked to the perceived acceptability of sleepy driving, such beliefs could be targeted in intervention efforts. It is important that research in this area continue in light of the serious threat that sleepy driving is posing to drivers and other road users.

In conclusion, the current study sought to compare the driving behaviours and perceptions of drink driving and sleepy driving, among young and older drivers. The main finding was that both younger and older drivers reported a greater likelihood of sleepy driving than drink driving, as well as reporting more positive attitudes toward sleepy driving and lower levels of perceived legitimacy of enforcement for sleepy driving than drink driving. Additionally, younger drivers reported significantly greater likelihood to drive while sleepy than older drivers. Efforts to increase *all drivers'* perceptions of the dangerousness of sleepy driving are seemingly warranted, as well as greater acknowledgement that continuing to drive while sleepy is a volitional behaviour and as such, can be avoided. Such efforts are important to reduce road trauma and provide a safer road environment for all road users.

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The impact of safety measures on the re-offence and crash rates of drink-driving offenders in Victoria

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Abstract

Alcohol is a major factor in road deaths and serious injuries. In Victoria, between 2008 and 2013, 30% of drivers killed were involved in alcohol-related crashes. From the early 1980s Victoria progressively introduced a series of measures, such as driver licence cancellation and alcohol interlocks, to reduce the level of drink-driving on Victoria's roads. This project tracked drink-driving offenders to measure and understand their re-offence and road trauma involvement levels during and after periods of licensing and driving interventions. The methodology controlled for exposure by aggregating crashes and traffic violations within relevant categories (e.g. licence cancelled/relicensed/relicensing not sought) and calculated as rates 'per thousand person-years'. Inferential statistical techniques were used to compare crash and offence rates between control and treatment groups across three distinct time periods, which coincided with the introduction of new interventions. This paper focuses on the extent to which the Victorian drink-driving measures have been successful in reducing re-offending and road trauma involvement during and after periods of licence interventions. It was found that a licence cancellation/ban is an effective drink-driving countermeasure as it reduced drink-driving offending and drink-driving crashes. Interlocks also had a positive effect on drink-driving offences as they were reduced during the interlock period as well as for the entire intervention period. Possible drink-driving policy implications are briefly discussed.

Introduction

Drink-driving continues to be a serious and persistent problem in Victoria as in other highly motorised jurisdictions, as alcohol-related crashes result in substantial fatalities and injuries. Alcohol-related crashes are one of the leading causes of death on the roads with 32% of Victorian driver fatalities between 2008 and 2011 having a BAC over zero (28% of driver fatalities had an illegal BAC and 10% had a BAC over 0.2) (Coroners Prevention Unit, 2013). The gravity of the problem is reflected in the enormous amount of literature that has focused on the personal and economic cost of drink-driving, as well as the development and implementation of various countermeasures to reduce the prevalence of the offending behaviour. Of particular concern is the proportion of repeat drink-driving offenders. For example within Victoria 30% of detected drink-drivers had a previous drink-drive conviction (Boorman, 2012).

Countermeasures to address drink-driving vary across different jurisdictions, although licence disqualification has historically formed the foundation of many legislative responses to such offending behaviours. The application of licensing sanctions has consistently proven an effective general and specific deterrent (Peck, 1991; Ross, 1992). However, drink-drivers are not a homogeneous group (Nochajski & Wieczorek, 2000), as research has demonstrated that first time and repeat offenders often differ in both characteristics and treatment needs (Stewart, Boase, & Lamble, 2004). Consequently these groups display a tendency to respond differently to the application of sanctions (Ferguson, Sheehan, Davey, & Watson, 1999; Freeman, 2004). More specifically, sanctions in isolation appear to be less effective in reducing alcohol-impaired driving among "hard-core" repeat offenders (Hedlund & McCartt, 2002), and there is evidence that some repeat offenders may in fact be immune or impervious to the threat of legal sanctions (Freeman, Liossis, & David, 2006). As a result, alcohol ignition interlocks are increasingly being combined with licence intervention in an effort to reduce the prevalence of re-offending, particularly among recidivist offenders. However, a common theme to emerge from the international literature is that while interlock devices are effective in preventing drink-driving recidivism while installed, re-offence rates are comparable between interlock and non-interlock drivers upon removal of the device (Willis, Lybrand, & Bellamy, 2004). Despite this, the utility of interlock devices to address the problem of drink-driving remains clearly apparent. As a result, policy makers are now varying the legislative use of interlock devices in an attempt to maximise the technology's ability to create lasting behaviour change.

In Victoria, such interventions have been progressively introduced over time. An examination of the impact of the approach on Victorian re-offence and crash rates was undertaken to asses the impact of such measures in the Victorian context. This examination is important to inform future policy development. More specifically, there is a need to accurately determine the impact of specific interventions not only on recidivism rates, but corresponding crash rates. In regards to the latter, there is a large body of literature that has demonstrated drink-drivers are disproportionately represented in crash statistics, particularly repeat offenders (Brown et al., 2002; Freeman et al., 2006; Hedlund & McCartt, 2002). Furthermore, there is a need to determine what may occur for convicted drink-drivers who elect not to install the interlock (e.g., the driver may drive unlicensed).

The current study involved an examination of a large sample of Victorian drink-drivers' responses to licence cancellation and interlocks in order to guide and inform future policies. This was achieved by examining whether these interventions influence offenders subsequent crash and re-offence rates. Therefore the study assesses the specific deterrence effects of these interventions in Victoria. Specifically, the research considered the impact of:

- Licence cancellation for drink-driving offenders before interlocks came into effect (1 January 1996 to 12 May 2002).
- Mandatory interlock fitment for repeat drink-drivers (13 May 2002 to 10 October 2006).
- Mandatory interlock fitment for repeat drink-drivers and drink-drivers with high BACs or younger drivers in the range greater than 0.07 BAC (11 October 2006 to 30 September 2014). It should be noted that for some low-range repeat offenders interlocks were discretionary.

Method

Drivers and riders convicted of a drink-driving offence (index offence) committed between 1 January 1996 and 30 September 2014 (inclusive) were considered eligible persons for analyses (N = 129,618). Data files relating to all offences (from 1 January 1986 to 30 September 2014), licence status changes, bans from driving, licence conditions, and driver and rider demographics were provided from the VicRoads Driver Licensing System (DLS). Data for the 10 years before the index offence were required to determine whether it was the first or repeat offence. The crash involvement file was provided from the VicRoads Road Crash Information System (RCIS).

The above changes were considered in relation to three time periods (stages) as outlined in the table below. These changes concern major legislation changes in Victorian drink-driving laws (e.g. introduction of interlocks). Offenders were assigned to groups as described in Table 1. It is noted that an interlock condition was not mandatory for all repeat offenders in Stage 3 (i.e., those with a low-range BAC). However, only those with an interlock condition applied were included in analyses relating to the interlock period. The results in this paper focus on drink-driving offences and drink-driving casualty crashes.

Table 1. Offender groups for analysis

Stage 1 **1 Jan 1996 to 12 May 2002** (N = 29,204)	**Stage 2** **13 May 2002 to 10 Oct 2006** (N = 37,143)	**Stage 3** **11 Oct 2006 to 30 Sept 2014** (N = 63,271)
Group A (N = 4,563) All drivers with an index drink-driving offence between 1 January 1996 and 12 May 2002 that had a prior drink-drive offence in the 10 years prior to the index offence (no interlocks)	**Group D** (N = 3,188) All drivers with an index drink-driving offence between 13 of May 2002 and 10 October 2006 that had prior drink-drive offence in the 10 years prior to the index offence (interlocks applied)	**Group G** (N = 8,662) All drivers with at least one drink-driving offence between 11 October 2006 and 30 September 2014 that had a prior drink-drive offence in the 10 years prior to the index offence (interlocks applied)
Group B (N = 8,713) All drivers with a drink-driving offence between 1 January 1996 and 12 May 2002 with a BAC >= 0.15 OR driver aged less than 25 or with a probationary licence with BAC > 0.07 and < 0.15 with no previous eligible offence in the 10 years prior to the index offence (no interlocks)	**Group E** (N = 9,155) All drivers with a drink-driving offence between 13 of May 2002 and 10 October 2006 with a BAC >= 0.15 OR driver aged less than 25 or with a probationary licence with BAC > 0.07 and < 0.15 with no previous eligible offence in the 10 years prior to the index offence (no interlocks)	**Group H** (N = 13,681) All drivers with a drink-driving offence between 11 October 2006 and 31 December 2013 with a BAC >= 0.15 OR driver aged less than 26 or with a probationary licence with BAC > 0.07 and < 0.15 with no previous drink-driving offence in the 10 years prior to the index offence (interlocks applied)
Group C (N = 15,928) All drivers with a drink-driving offence between 1st January 1996 and 12 May 2002 that do not fit into **A** or **B** (no interlocks)	**Group F** (N = 24,800) All drivers with a drink-driving offence between 13th of May 2002 and 10th October 2006 that do not fit into **D** or **E** (no interlocks)	**Group I** (N = 40,928) All drivers with a drink-driving offence between 11th October 2006 and 31st December 2013 that do not fit into **G** or **H** (no interlocks)

The analyses were conducted in three phases.

Phase 1 - Crash and offence rates during and after licence cancellation (Stage 1 offenders)

This phase applied to Stage 1 offenders only, with a drink-driving offence between1 January 1996 and 12 May 2002. For all Stage 1 groups combined (A+B+C), crashes and drink-driving offences were aggregated within relevant licensing/intervention periods (licence ban/relicensed) and then calculated as offence and crash rates with the related metric of 'per thousand person-years' as the denominator (Siskind, 1996). Offence and crash rates were calculated for the period between the offence and the start of the licence ban; the licence ban period, the post-licence restoration period, and the post-ban unlicensed period (where re-licensing was not sought). In order to test the differences in rates across the different licence/intervention periods, rate ratios were calculated separately for drink-driving crash rates and drink-driving offence rates and compared.

Phase 2 - Mandatory interlocks for repeat drink-drivers (Stage 2 offenders)

As with Phase 1, the rates of offences and drink-driving crashes were calculated per thousand person-years for all the licence/intervention periods. In addition, rates for the period of interlock condition and the post-interlock licence restoration period (after completion of an interlock condition) were also calculated for those offenders eligible for this condition. In order to evaluate the effectiveness of interlocks for repeat drink-drivers, treatment and control groups were identified as follows (Table 1):

- Pre-treatment group (Group A – repeat offenders no interlock)
- Post-treatment group (Group D – repeat offenders interlock)
- Pre-control group (Groups B and C – all other drink-drivers no interlock before change)
- Post-control group (Groups E and F – all other drink-drivers no interlock after change)

Rate ratios were calculated for the pre- and post-periods separately for the treatment and control groups for each licence intervention period and for the entire pre- and post-periods.

Phase 3 - Mandatory interlocks for drink-drivers with a BAC of equal to or greater than 0.15 - or less than 26 years for a probationary licence holder with BAC greater than 0.07 (Stage 3 offenders)

As with Phases 1 and 2, the rates of drink-driving offences and drink-driving crashes were calculated per thousand person-years for all the licence/intervention periods. In order to evaluate the effectiveness of interlocks for these high-range offenders, treatment and control groups were identified as follows (Table 1):

- Pre-treatment group (Group E – no interlock – before change)
- Post-treatment group (Group H – interlock – after change)
- Pre-control group – non-repeat (Group F – other offenders – no interlock – before change)
- Post-control group – non-repeat (Group I – other offenders – no interlock – after change)

Rate ratios were calculated comparing pre to post separately for the treatment and control groups for each licence/intervention period and for the entire pre and post periods.

Statistical significance testing

For the three phases, confidence intervals for each of the rate ratios were also calculated based on an alpha level of .05. Interpretations of statistically significant differences in rates were based on the confidence interval not including the value 1. For Phases 2 and 3, comparisons between the control rate ratios and the treatment rate ratios were completed using the difference in the log of the rate ratios and a Z-test for statistical significance. Note that for Phases 2 and 3 the specific effect of the interlock was analysed separately to the other licence intervention periods. Althought the analyses of the licence intervention periods analyse the period after the interlock, results are indicative of whether the licence cancellation and interlock regime work as whole package.

Results

Phase 1 - Crash and offence rates during and after licence cancellation

Stage 1 offenders had a statistically significantly lower rate of drink-driving offending during licence bans compared to the pre-licence ban and post-licence restoration periods by 70% and 47% respectively (Rate Ratio (RR) = 0.30 and 0.53 respectively). There was, however, no statistically significant difference in rates of drink-driving offending between the ban period and the unlicensed period (those who did not re-licence after cancellation) (RR = 1.05). The offending rates were statistically significantly lower during the unlicensed period compared to the post-licence restoration period by 44% (RR= 0.56). Finally, the post-licence restoration period had a statistically significantly lower rate of offending by 43% compared to the pre-licence ban period (RR = 0.57) (Table 2).

There was a statistically significantly lower rate of drink-driving crash involvement during licence bans compared to the pre-licence ban and post-licence restoration periods by 79% and 55% respectively (RRs = 0.21 and 0.45 respectively). There was, however, no statistically significant difference in rates of drink-driving crash involvement between the licence ban period and the unlicensed period (RR = 1.17). The drink-driving crash rates were statistically significantly lower during the (post ban) unlicensed period compared to the post-licence restoration period by 47% (RR = 0.53). Finally, the post-licence restoration period had a statistically significantly lower rate of drink-driving crash involvement compared to the pre-licence ban period by 53% (RR = 0.47) (Table 2).

Table 2: Offence rate ratios all Stage 1 groups

Comparison	Rate ratio (95% CI)	
	Drink-driving offences	Drink-driving crashes
Licence ban vs. Pre-licence ban	0.30* (0.27 – 0.33)	0.21* (0.15 – 0.30)
Licence ban vs. Post-licence restoration	0.53* (0.49 – 0.57)	0.45* (0.34 – 0.60)
Unlicensed vs. Licence ban	1.05 (0.92 – 1.21)	0.85 (0.50 – 1.47)
Unlicensed vs. Post-licence restoration	0.56* (0.49 – 0.63)	0.53* (0.32 – 0.86)
Post-licence restoration vs. Pre-licence ban	0.57* (0.53 – 0.62)	0.47* (0.35 – 0.62)

* Rate ratios statistically significant p < .05

Phase 2 - Mandatory interlocks and licence intervention periods for repeat drink-drivers

Effect of the interlock period

The interlock period was assessed with rate ratios by comparing post-treatment recidivists' (Group D) interlock period versus pre-treatment recidivists' (Group A) post-licence restoration period. This rate ratio was then compared to the rate ratio for pre- to post-control licence restoration period. The post-treatment recidivists had a statistically significantly lower (by 81%) drink-driving offence rate (RR = 0.19, 95% CI [0.10 – 0.35]) during their interlock period compared to the pre-treatment recidivists during their post-licence restoration period. For the pre- versus post-control licence restoration period, there were also statistically significant reductions for drink-driving offences (0.90, 10% reduction). However, this reduction was not to the same level as for the treatment groups (Z = -4.88, p < .001), indicating the interlock had been effective in reducing drink-driving offences. There were no drink-driving casualty crashes during the interlock period for the post-treatment recidivists, so the rate ratio was not able to be calculated.

Drink-driving offences for other licence intervention periods

For drink-driving offences (Figure 1), the rate decreased from pre- to post-treatment over the entire period by 12% (RR = 0.88, 95% CI [0.81 – 0.97]), but not in any specific licensing/intervention period. For the control groups, there were some statistically significant reductions from pre- to post-control, but none statistically significantly different from the pre- to post-treatment groups with the exception of the period between index offence and licence ban. For this period, there was a statistically significant 32% reduction for the pre- to post-controls (RR = 0.68, 95% CI [0.60 – 0.76]), but not for the pre- to post-treatment (RR = 0.97, 95% CI [0.76 – 1.25]) (Z = 2.54, p = .011). Therefore, the licence intervention periods did not have an effect on these offences.

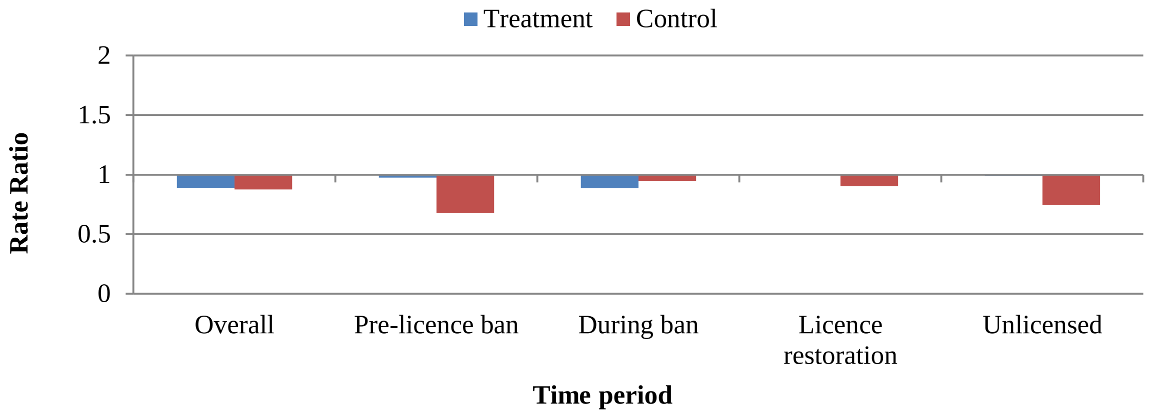

Figure 1. Rate ratios pre to post drink-driving offences for each period by treatment and control

Drink-driving casualty crashes for other licence intervention periods

The drink-driving (Figure 2) crash rates showed no statistically significant change from pre-treatment to post-treatment for recidivists with the exception of the entire stage reducing drink-driving casualty crashes by 44% (RR = 0.56, 95% CI [0.32 – 0.98]). However, there was also a similar level of reduction in this period from pre-control to post-control by 36% (RR = 0.64, 95% CI [0.53 – 0.76], Z = -.42, p = .674). Therefore, the licence intervention periods did not have an effect on these crashes.

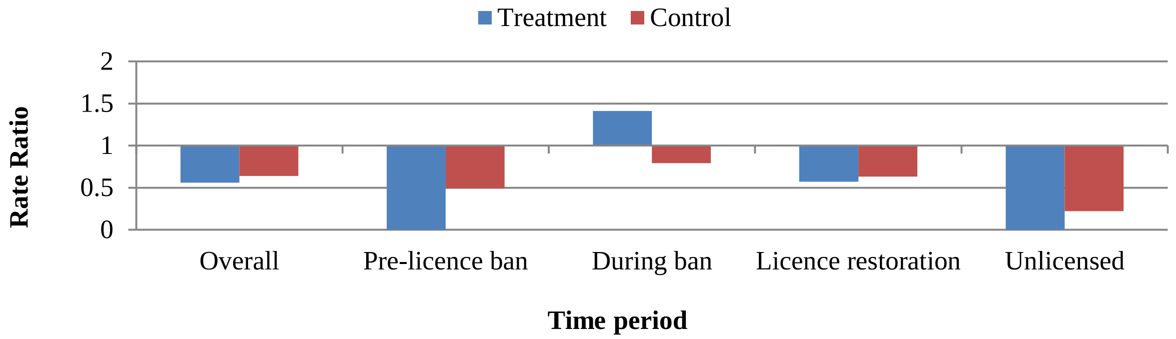

Figure 2: Rate ratios pre to post drink-driving casualty crashes for each period by treatment and control

Phase 3 - Mandatory interlocks and licence intervention periods for drink-drivers with a BAC of equal to or greater than 0.15 - or less than 26 years of age for a probationary licence holder with BAC greater than 0.07 (Stage 3)

Effect of the interlock period

The post-treatment group had statistically significantly lower drink driving offence (RR = 0.37, 63% lower) and drink driving crash rates (RR = 0.19, 81% lower) during their interlock period compared to the pre-treatment group during their post-licence restoration period**.** There was also a statistically significant reduction for drink-driving offences from pre- to post-control (RR = 0.64, 36% reduction). However, this reduction was not as large as those found for the treatment groups (Z = -7.07, p < .001), indicating a positive effect of the interlock condition. There was no statistically significant difference between treatment and control on the level of reduction for drink-driving crashes (Table 3). The small sample size for drink-driving casualty crashes may have resulted in insufficient power for a statistical significance, and therefore the results for crashes were inconclusive.

Table 3: Post-treatment (interlock period) versus pre-treatment (licence restoration) compared to post-control versus pre-control (licence restoration) crash and offence rates

	Post-treatment (interlock) vs. Pre-treatment (no interlock) (95% CI)	Post-control (no interlock) vs. Pre-control (no interlock) (95% CI)	Statistical significance
Drink-driving casualty crashes	0.19[1] (0.08 – 0.46)	0.38[1] (0.29 – 0.51)	Z = -1.46, p = .144
Drink-driving offences	0.37[1] (0.32 – 0.42)	0.64[1] (0.60 – 0.68)	Z = 7.07*, p < .001

*Statistically significant difference between treatment and control rate ratios (p < .05)
[1]Statistically significant rate ratios (post versus pre) (p < .05)

Drink-driving offences for other licence intervention periods

The rate of drink-driving offending (Figure 3) statistically significantly decreased by 38% overall (RR = 0.62, 95% CI [0.57 – 0.67]) and for the post-licence restoration period by 56% (RR = 0.44, 95% CI [0.40 – 0.49]) from pre-treatment to post-treatment (Groups E to H).

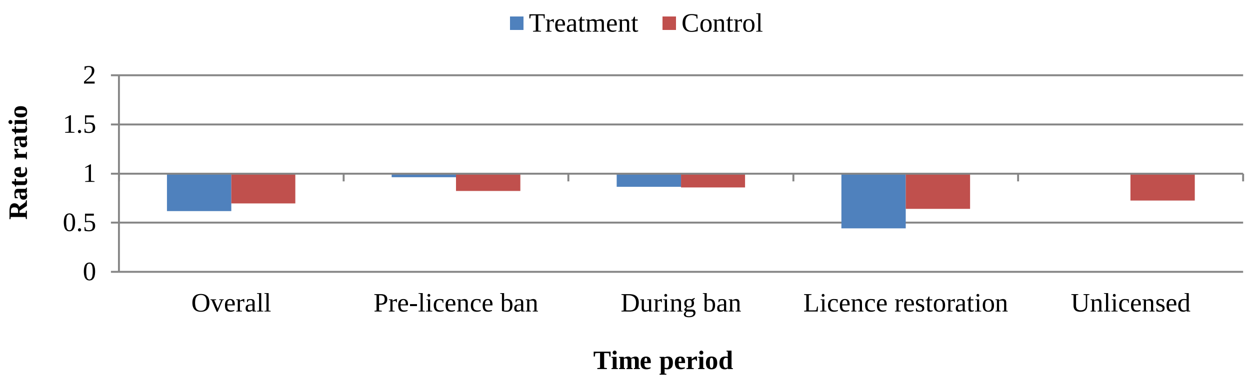

Figure 3: Rate ratios pre to post drink-driving offences for each period by treatment and control

There were no statistically significant reductions for any other period. While there were reductions from pre- to post-control (Groups F and I) for the post-licence restoration period by 36% (RR = 0.64, 95% CI [0.60 – 0.68]) and by 30% overall (RR = 0.70, 95% CI [0.66 – 0.73]), these reductions were not as large as those found for the treatment groups (Z = -6.38, p < .001 and Z = -2.57, p = .010 respectively), indicating that the licence intervention periods have been effective. The specific effect of the interlock, analysed in the same way as described above, is discussed below (Table 3).

Drink-driving casualty crashes for other licence intervention periods

The rate of drink-driving crashes (Figure 4) statistically significantly decreased by 66% overall (RR = 0.34, 95% CI [0.24 – 50]) and by 77% for the post-licence restoration period (RR = 0.23, 95% CI [0.14 – 0.36]) from pre-treatment to post-treatment. There were no statistically significant reductions for any other period. There were also statistically significant reductions from pre- and post-control by 62% for the post-licence restoration period (RR = 0.38, 95% CI [0.29 – 0.51]) and by 80% overall (RR = 0.20, 95% CI [0.16 – 0.25]), and this reduction was greater than the reduction for the treatment groups (Z = 5.18, p < .001). Therefore the licence intervention periods had no effect on drink-driving casualty crashes.

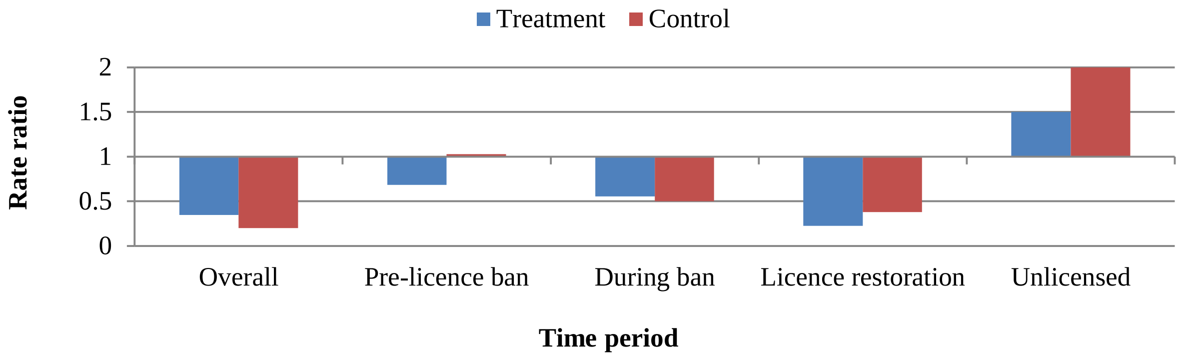

Figure 4: Rate ratios pre to post drink-driving crashes for each period by treatment and control

Discussion and Implications

The aim of this paper was to determine drink-driving casualty crash and offence rates during and after licence cancellation and/or an interlock condition. Given some evidence that licence disqualification in isolation may not prevent drink-driving recidivism among repeat or high-range offenders (Ahlin, Rauch, Zador, Baum, & Duncan, 2002; Freeman et al., 2006), sanctions have more recently been increasingly combined with interlock installation (Bailey, Lindsay, & Royals, 2013).

Results of Phase 1 of this study suggest that licence bans had a positive road safety effect while drivers were disqualified from driving, with reductions of up to 70% observed in drink-driving offences and up to 79% reductions in drink-driving casualty crashes while they were banned. This finding is consistent with a large body of research that has generally demonstrated licence disqualification periods to be one of the most effective methods for reducing further drink-driving offences (Jones & Lacey, 1991; McArthur & Kraus, 1999; Nichais & Ross, 1991; Peck, 1991). Additionally, evidence emerged that indicated licence bans had an on-going positive impact once offenders were re-licensed, with post-ban offending rates being lower than the rates prior to the ban. This is again consistent with previous research that has demonstrated licence bans have a specific deterrent effect (Homel, 1988; Siskind, 1996). There was evidence that some individuals offended even while on a ban. That is, they were detected drink-driving while unlicensed, demonstrating that licence ban does not have the desired impact on some individuals. This is again consistent with research that has reported unlicensed driving is often combined with other illegal behaviours such as drink-driving (Watson, 2004).

A key finding to emerge from the study was that the highest rate of drink-driving offences and drink-driving casualty crashes was actually during the period between being detected by police (the index offence) and the commencement of the licence ban. That is, the group were most likely to drink and drive after they had been apprehended by the police, but had yet to attend court and/or receive a licence ban. This finding has clear implications in regards to immediate licence loss at the time of offence for all drink-driving offenders.

Encouragingly, and consistent with previous research (Bailey et al., 2013), Phase 2 and 3 analyses found that interlock conditions had a positive effect. That is, a statistically significantly lower rate of drink-driving offending for the interlock period was evident for those who received an interlock condition for repeat drink-drivers and for a higher level BAC first time offence and young drink drivers. This can be considered to represent either a treatment effect (whereby offenders decide to change their drinking and driving behaviours) or an incapacitatory effect (which is associated with being unable to start a vehicle once the driver has been drinking). Overseas research suggests that interlocks are effective in incapacitating or restricting individuals from drink-driving whilst installed in the vehicle, but the device appears to provide few long-term benefits as post-interlock recidivism rates are similar to those of control groups (Elder et al., 2011; Frank, Raub, Lucke, & Wark, 2002). For the current study, however, a legislative change that required high BAC offenders to install an interlock, resulted in a reduction in subsequent drink-driving offences even after the interlock condition was completed. This result again confirms the positive road safety effect of interlocks in regards to reducing the likelihood of drink-driving and provides some suggestion of long-term benefits for using interlocks with all repeat and first-time high range offenders.

For crashes, it is noted that an overall reduction in drink-driving casualty crashes across the entire licence/intervention period was identified for both the treatment (e.g., recidivist and high BAC interlock groups) and control groups. While a general reduction is positive, it is not specifically related to the interlock condition as the reduction was similar for both treatment and control groups. This finding is somewhat inconsistent with a small body of research that has demonstrated interlock installation has a positive effect on crash reduction (Bjerre, 2005). However, it should also be noted that because crashes are relatively rare events, it sometimes difficult to detect effects due to lack of power. Also, some offenders most likely did not install the required interlock, and thus, they may have chosen to drive more safely (and less often) as a result of being disqualified from driving. It is noteworthy that research has demonstrated a proportion of suspended drink-driving offenders may continue to drive without a licence or insurance (McCartt, Geary, & Berning, 2003).

In terms of policy development in this area, it may be worth considering requiring offenders to undergo a drink-driving related intervention or other effective alcohol treatment program, especially for those with alcohol dependence. It is also possible to consider applying a brief intervention to such offenders whilst they await their court date. Brief interventions are a treatment approach that aim to change behaviour by motivating individuals who use alcohol at harmful levels to reduce their alcohol misuse. This behaviour change approach is about motivating participants, not educating or informing them (Filtness, Sheehan, Fleiter, Armstrong, & Freeman, 2015). It may also be necessary to extend the interlock period for as long as the driver continues to have an alcohol problem. However, the effectiveness of a permanent fitment strategy remains unknown.

This study focused primarily on the specific deterrence effects of these interventions and general deterrence was not able to be directly assessed. The study was not able to identify which offenders had an interlock installed, just that they had an interlock condition applied to their licence. As a result, it is possible that some of the effects may be diluted as sn interlock condition would operate in a similar way to a ban if the interlock is not installed. A further limitation of this study is that the control groups were not matched and had characteristic differences in terms of offence profile that may have affected the results. It is not possible to determine if changes unrelated to the introduction of interlocks (e.g., enforcement, media) affected the control groups differently to the treatment groups.

This study has provided evidence within Victoria, Australia, that bans from driving and alcohol ignition interlocks are effective safety interventions for reducing drink-driving rates for offenders as well as improving overall road safety. This confirms the applicability of these interventions within the Australian context.

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How serious are they? The use of data linkage to explore different definitions of serious road crash injuries

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Abstract

Over recent years, the focus in road safety has shifted towards a greater understanding of road crash serious injuries in addition to fatalities. Police reported crash data are often the primary source of crash information; however, the definition of serious injury within these data is not consistent across jurisdictions and may not be accurately operationalised. This study examined the linkage of police-reported road crash data with hospital data to explore the potential for linked data to enhance the quantification of serious injury. Data from the Queensland Road Crash Database (QRCD), the Queensland Hospital Admitted Patients Data Collection (QHAPDC), Emergency Department Information System (EDIS), and the Queensland Injury Surveillance Unit (QISU) for the year 2009 were linked. Nine different estimates of serious road crash injury were produced. Results showed that there was a large amount of variation in the estimates of the number and profile of serious road crash injuries depending on the definition or measure used. The results also showed that as the definition of serious injury becomes more precise the vulnerable road users become more prominent. These results have major implications in terms of how serious injuries are identified for reporting purposes. Depending on the definitions used, the calculation of cost and understanding of the impact of serious injuries would vary greatly. This study has shown how data linkage can be used to investigate issues of data quality. It has also demonstrated the potential improvements to the understanding of the road safety problem, particularly serious injury, by conducting data linkage.

Introduction

In order to reduce the burden of road crash injuries, there is a need to fully understand the nature and contributing circumstances of crashes and the resulting injuries. The National Road Safety Strategy 2011-2020 (Australian Transport Council, 2011) outlines plans to reduce the burden of road trauma via improvements and interventions relating to safe roads, safe speeds, safe vehicles, and safe people. It also highlights that a key aspect in achieving these goals is the availability of comprehensive data on road crashes and related injuries. The use of data is essential so that more in-depth epidemiologic studies of risk profiles can be conducted as well as enable effective monitoring and evaluation of road safety interventions and programs.

Over the years there have been significant reductions in fatalities in Australia (The Parliament of Victoria Road Safety Committee, 2014), as there has been in many other highly motorised countries (International Traffic Safety Data and Analysis Group (IRTAD), 2011). However, there has been less of a reduction (and in some cases an increase) in the number of serious non-fatal road crash injuries in many of these jurisdictions, including Australia. This in combination with the substantial burden of serious non-fatal road crash injuries has meant that nationally and internationally, the focus in road safety has shifted towards a greater understanding of road crash serious injuries in addition to fatalities (International Traffic Safety Data and Analysis Group (IRTAD), 2011; The Parliament of Victoria Road Safety Committee, 2014). Police reported crash data are the primary source of crash information in most jurisdictions (International Traffic Safety Data and Analysis Group (IRTAD), 2011). Unfortunately, however, the definition of serious injury within police-reported data is not consistent across jurisdictions and may not be accurately operationalised, which could lead to misleading estimates of the impact and cost of crashes (D'Elia & Newstead, 2015).

The definition of a fatality is relatively consistent across countries since it is based on that of the Organisation for Economic Co-operation and Development (OECD) whereby a traffic death is one that occurs within 30 days of a road crash. In terms of other severity levels, particularly in relation to serious injury, the definitions are much more variable (D'Elia & Newstead, 2015). Many of the countries in the OECD define a serious injury as a person who is admitted to hospital for 24 hours or more as a result of a road crash (World Health Organization, 2010). However, this definition generally relies on the police identifying seriously injured persons based on whether they were transported to hospital or not. Given the reported lack of liaising between police and hospitals on whether admission actually occurred or on the length of admission, a serious injury category using this definition could range from cuts and bruises to severe head injuries (Ward et al., 2010). Another study by the authors (Watson, Watson, & Vallmuur, 2013), suggest that the 'hospitalisation' severity category used by police does not reflect true hospitalisations in all cases, at least within the state of Queensland. Further, it highlighted the wide variety of severity levels within hospitalised cases that are not captured by the current police-reported definitions.

As a result of this broad, and likely inconsistent, serious injury classification, more objective and precise measures of severity, based on threat to life, have been proposed (International Traffic Safety Data and Analysis Group (IRTAD), 2011) which rely on either police assigning a nature of injury code or on the use of hospital discharge diagnoses (e.g., Abbreviated Injury Scale, ICISS). The Abbreviated Injury Scale (AIS) is a body-region based coding system developed by the Association for the Advancement of Automotive Medicine (Association for the Advancement of Automotive Medicine, 2008). A single injury is classified on a scale from 1-6 (1 = minor; 2 = moderate; 3 = serious; 4 = severe; 5 = critical; and 6 = maximum). Another example of a more precise measure of severity is the International Classification of Diseases–based Injury Severity Score (ICISS) (Osler, Rutledge, Deis, & Bedrick, 1996). ICISS involves using ICD diagnoses to calculate threat-to-life associated with an injury. Survival Risk Ratios (SRR) are based on studies using large hospital datasets with death outcomes and the calculation of the survival probability (proportion of cases who do not die) for each ICD code (e.g., Stephenson, Langley, Henley, & Harrison, 2003). Cases are then assigned an ICISS, which is the multiplication of SRRs of all their diagnoses. It should be noted that there is some debate surrounding the most appropriate injury severity classifications, however these two measures are widely accepted and often used in injury research as reasonably reliable measures of the probability of death (Langley & Cryer, 2012; Stephenson, Langley, Henley, & Harrison, 2003). While it is acknowledged that hospital staff do not generally have training in the direct assignment of 'threat to life' measures, they are trained in assigning ICD diagnoses which can be mapped to AIS and/or SRRs using data obtained from trauma studies (e.g., Stephenson, Langley, Henley, & Harrison, 2003).

It could be suggested, however, that even if more detailed information was collected in order to assign these more objective and/or precise measures, the police are not necessarily in the best position to collect this information. Police do not have the training or expertise to record information on the nature of an injury, or injuries, with the required level of accuracy. Also, even if they were trained to assess this, classifying injury at the scene of a crash could be problematic, as not all injuries are apparent at the scene and the police have many competing priorities in these situations (e.g., traffic control). Also, it is argued that the consistency of the recorded information from case to case could be questionable if collected by the police (Amoros, Martin, Chiron, & Laumon, 2007; Chapman & Rosman, 2008; Farmer, 2003; McDonald, Davie, & Langley, 2009; Ward et al., 2010). The World Health Organisation (2010) suggests some possible strategies for addressing the issue of serious road crash injuries, including data linkage between police and hospital databases either routinely or periodically to check the accuracy of the police data; and/or the following up of cases by police (or reported by the hospital) to determine the length of the hospital stay.

This study aimed to examine the first of these strategies, namely the linkage of police-reported road crash data with a comprehensive linked hospital data set (including emergency department presentations and admitted patients' data). It specifically examines the potential for linked data to enhance the quantification of serious injury for those cases that link with police-reported data. It also explores issues such as under-reporting of road crash injuries to police and the different road user profiles of serious injury using different combinations of data and different definitions of serious injury.

Methods

Ethics approval was obtained from the Queensland Health Human Research Ethics Committee (#HREC/12/QHC/45).

Data collections

Data were provided from the Queensland Road Crash Database (QRCD), Queensland Hospital Admitted Patients Data Collection (QHAPDC), Emergency Department Information System (EDIS), and Queensland Injury Surveillance Unit (QISU) by each relevant custodian for the specified cases for 2009. The year 2009 was used as it was the most recently available data for all collections at the time the linkage was commenced. There are often significant delays with data being available to researchers. Also, gaining the necessary custodian approvals and the data linkage (conducted by the Queensland Health Record Linkage Group) took twenty months to complete. The QRCD includes all road crash injuries reported to police in Queensland in 2009. This includes information about all persons injured on public roads, including drivers, passengers, motorcycle riders, cyclists, and pedestrians. It should be noted that the following major exclusions apply:

- The incident occurs in an area outside the road or road related area.
- There is no moving vehicle involved.
- The incident is not attributable to vehicle movement.

It should be noted that the definition of what constitutes a road crash injury in this study is based on this QRCD definition

QHAPDC contains data on all patients discharged, statistically separated, died, or transferred from a Queensland hospital permitted to admit patients (including public hospitals, licensed private hospitals, and day surgery units). External cause of injury information is captured in three data fields (i.e., external cause, place, and activity) using International Classification of Diseases 10th Edition, Australian Modification (ICD-10-AM) (National Centre for Classification in Health, 2004).

The Emergency Department Information System (EDIS) includes all emergency department presentations in twenty-nine hospitals across Queensland (approximately 75% of Queensland emergency departments). This collection does not code cause of injury information and requires the use of the 'presenting problem' text description to identify transport-related cases. However, the principal diagnosis is coded using ICD-10-AM.

The Queensland Injury Surveillance Unit collects data on injuries presenting at seventeen Queensland emergency departments (nine of the QISU hospital emergency departments are not included in EDIS). This collection captures cause of injury information in several data fields both coded and text-based, including: mechanism, external cause, major injury factor, place, activity, and an 'injury description' text field.

The following was determined as the selection criteria for each collection were used to capture of the population of interest:

- QRCD: all police-reported injury cases
- QHAPDC: all admitted patients cases coded as transport-related (ICD-10-AM External Cause Codes from V00-V99)
- EDIS: all emergency department cases coded as an injury (discharge diagnosis S00-S99 and T00-T98)
- QISU: all emergency department injury cases coded as transport-related (external definition of 'motor vehicle – driver'; 'motor vehicle – passenger'; 'motorcycle – driver'; 'motorcycle – passenger'; 'pedal cyclist or pedal cyclist passenger'; and 'pedestrian')

It should be noted that for the data linkage component (conducted by the Queensland Health Record Linkage Group), all injury cases in EDIS and all transport injury cases in QISU and QHAPDC were processed for linkage. This was done as there was some question over the accuracy of the coding of traffic (road-related) injuries in QHAPDC and QISU and the selection of transport injuries in EDIS (as this data collection only contains cause of injury information in an unstructured text field as described above). So, in order to capture those cases that may still link to the QRCD (police-reported data) despite not being coded or identified as a road crash in the three hospital data sets, a broader approach to the linkage was used. The researchers then applied the refinements described in the next section to identify relevant road crash cases for analysis.

Data linkage process

Person details and demographic data were linked using deterministic & probabilistic methodologies, as well as manual clerical reviews where required. QRCD was merged with the other data collections. The data sets were merged based on the person ID. If the person ID of a QRCD case matched the person ID of any case in the other data sets, then the case was considered to be a link and was coded as such. Non-links were all cases in QRCD that did not have a person ID in common with any case in the other data collections. Non-links, for the purposes of calculating under-reporting, were all cases in the other data collection that did not have a person ID in common with QRCD. The hospital (i.e., presented at hospital) data collections (i.e., QHAPDC, EDIS, and QISU) were combined to form a *hospital population* data set. This data set included all cases from each collection that linked to each other as well as the unique (non-linked) cases from each data collection. This combined data set was then used as the basis for the population estimates for comparison to QRCD.

Selection of cases and coding of variables

The selection of road crashes for each data collection was as follows:

- QRCD – all casualties
- QHAPDC – All acute admissions with ICD-10-AM External Cause Codes from V00-V89 and fourth character of 'traffic'
- QISU – All cases with an *External definition* (Motor vehicle – driver; Motor vehicle – passenger; Motorcycle – driver; Motorcycle – passenger; Pedal cyclist or pedal cyclist passenger; Pedestrian) and *type of place* (street/highway)
- EDIS – All cases with a *Presenting problem* keyword search relating to crashes (e.g., car, motorbike, pedestrian) without exclusion terms (e.g., off-road, track)

The Abbreviated Injury Scale (AIS) was coded as (1 = minor; 2 = moderate; 3 = serious; 4 = severe; 5 = critical; and 6 = maximum). The Survival Risk Ratio (SRR) is an estimate of the probability of death from 0 (no chance of survival) to 1 (100% chance of survival). These two severity indicators were coded for QHAPDC, QISU, and EDIS using the *Principal diagnosis* ICD-10-AM codes mapped to the AIS and a SRR. SRR was mapped to ICD-10-AM using the values assigned from Stephenson and colleagues (2003). A tool for mapping ICD-10 codes to AIS score was sourced from the European Center for Injury Prevention. While this mapping is for ICD-10 to AIS, not ICD-10-AM, the principal diagnosis coding is compatible between the systems at a lower level of specificity (4th character).

Road user was coded as 1 = Driver, 2 = Motorcyclist, 3 = Cyclist, 4 = Pedestrian; 5 = Car passenger. The following variables were used for each of the data collections:

- QRCD – *casualty road user type*
- QHAPDC – second and fourth characters of the ICD-10-AM *external cause code*.
- QISU – *external code* (motor vehicle – driver = driver; motorcycle – driver and motorcycle – passenger = motorcyclist; pedal cyclist or pedal cyclist passenger = cyclist; pedestrian = pedestrian; motor vehicle passenger = passenger)
- EDIS – *Presenting problem* text search (e.g., driver = driver; motorcycle, MCA, MBA = motorcyclist; bicycle, PBS, PBA = cyclist; passenger = passenger; none of the keywords = unspecified)

In cases where more than one health data collection was combined with QRCD, there was a hierarchy for selection of which data collection would provide the data in the variables. For example, if the case has a specified ICD-10-AM principal diagnosis code in QHAPDC, this was the code that was used. The ICD-10-AM coding in QISU was used when QHAPDC was not available and the ICD-10-AM code for EDIS was used in cases where neither QHAPDC nor QISU code is available. This hierarchy was based on the assumption that QHAPDC coding of injury is superior to QISU and EDIS, as it is completed by trained coders with access to the full medical records of the patients. QISU would be considered next best, as it has coded information for most variables, and EDIS last, as many of the variables rely on being created from text searching.

Serious injury definitions

Using the different combinations of linked and non-linked data, the following estimates of the number of serious injuries were produced:

1. Police reported ‘hospitalisations’ (QRCD)
2. Hospital attendances (EDIS, QHAPDC, QISU)
3. Hospital admissions of 24hrs or more (QHAPDC)
4. Confirmed hospital attendances reported to police (QRCD linked with hospital)
5. Confirmed hospital admissions of 24hrs or more reported to police (QRCD linked with QHAPDC)
6. Confirmed serious injuries as defined by AIS > 3 reported to police (QRCD linked with hospital)
7. Confirmed serious injuries as defined by SRR < .942 reported to police (QRCD linked with hospital)
8. Hospital serious injuries as defined by AIS > 3 (QHAPDC, EDIS, QISU)
9. Hospital serious injuries as defined by SRR < .942 (QHAPDC, EDIS, QISU)

It should be noted that 'hospitalisations' in QRCD are defined as 'taken to hospital'.

The road user profile was compared for each of the serious injury definitions and population combinations outlined above.

Results

As shown in Table 1, the number of serious road crash injuries identified as occurring in Queensland in 2009 differs depending on both the population source and the definition of a serious injury. Based on the current practice in Queensland (police-reported 'hospitalised' - taken to hospital), approximately 6,500 cases would be defined as serious. If the number of police-reported road crash injuries that were actually 'taken to hospital' is considered (based on the cases linked with the hospital data set), the number of serious injuries rises to approximately 10,000. Using police-reported cases as the population, the highest number of serious injuries would be obtained by including all cases that are reported to police (i.e., are included in the QRCD) and attend hospital (i.e., link with the hospital data set). The lowest numbers of serious cases are identified from police reported cases that have an AIS higher than 3. When examining serious injury for cases identified in the *hospital data set* (not necessarily reported to police), attending hospital definition of serious yields the highest number of serious injuries. If the international definition of a serious injury ('hospitalised' for 24 hours or more) is applied, almost 30% of *police reported and defined as 'hospitalised'* fit this definition. This number doubles if the entire *hospital data set* is used (regardless of whether the case is reported to police). It should also be noted that as the definition of a serious injury becomes more specific (i.e., AIS and SRR), the discordance between police reported and the *hospital data* cases (under-reporting) narrows. However, even for the AIS and SRR defined serious *hospital data* cases, between 30% and 40% were not linked to police data.

Table 1: Number of police reported and hospital serious injuries based on different definitions

Definition	Police reported	Hospital cases	% Discordance
Police definition 'hospitalised'	6,674	-	
Attended hospital	10,649	29,261	63.6
Admitted hospital > 24hrs	1,879	3,474	45.9
AIS > 2	672	1,110	39.5
SRR < .942	1,041	1,507	30.9

As shown in Table 2, the road user profile for *police-reported and defined as 'hospitalised'* (i.e., police-reported taken to hospital) and the *police-reported attending hospital* were very similar. Within the police-reported serious injuries, the road user profile was different for the more specific definitions of serious injury (e.g., SRR and AIS), with a greater proportion of motorcyclists, cyclists, and pedestrians. It should be noted however that the majority of police-reported serious injuries were drivers and passengers regardless of the serious injury definition applied. In contrast, when all cases were considered regardless of whether the injury was reported to police (i.e., hospital data cases), motorcyclists and cyclists together formed the majority of cases. Within the hospital data cases, there was some variation based on the definition of serious injury utilised. Specifically, based on the *admitted to hospital for 24 hours or more* serious injury definition, there was a higher proportion of motorcyclists, while there was a higher proportion of cyclists if the *attending hospital* definition is used.

Table 2: Profiles of road crash serious injuries by road user type for Queensland in 2009

Variable	Level	Police 'hospitalised' %	Confirmed Attended %	Confirmed Admitted > 24hrs %	Confirmed AIS > 2 %	Confirmed SRR < .942 %
Police-reported						
Road user	Driver	53.6	55.1	39.9	39.6	44.9
	Motorcyclist	14.3	12.6	24.7	21.1	17.8
	Cyclist	5.3	4.8	6.4	6.5	6.2
	Pedestrian	6.4	5.6	10.9	12.4	11.0
	Passenger	20.5	21.9	18.1	20.4	20.2
Hospital data cases						
		Police 'hospitalised' %	Attended %	Admitted > 24hrs %	AIS > 2 %	SRR < .942 %
Road user	Driver	-	23.3	25.0	25.7	30.1
	Motorcyclist	-	29.7	38.4	33.9	26.9
	Cyclist	-	29.2	14.4	16.1	18.0
	Pedestrian	-	3.4	8.5	9.9	9.3
	Passenger	-	14.5	13.7	14.4	15.6

Discussion

This analysis of the various Queensland road crash and hospital data collections has shown that there was a large amount of variation in the estimates of serious road crash injuries depending on the population of reference and the definition or measure used. If the current reporting practice definition within the police data is used (i.e., police-reported 'hospitalised'), there were around 6,000 serious road crash injuries in 2009. If the number of police-reported road crash injuries that were actually 'taken to hospital' is considered (based on the cases linked with the hospital data), the number of serious injuries rises to approximately 10,000. If the international definition of a serious road crash injury is applied (i.e., admitted to hospital for 24 hours or more), there was slightly less than 2,000 serious road crash injuries reported to police. When AIS and SRR are used to classify serious injury the numbers are approximately 600 (AIS > 3) and 1,000 (SRR < .942) serious injuries respectively, reported to police. The number of serious injuries increases dramatically, if all injury cases are considered, not just those reported to police. Specifically, if all cases 'taken to hospital' (regardless of whether they are reported to police) are counted, there were almost 30,000 serious injuries. In contrast, if the admitted to hospital for 24 hours or more definition is used then there were around 3,500 cases, while AIS and SRR based definitions provided estimates of approximately 1,000 and 1,500 cases respectively.

It should also be noted that as the definition of serious becomes more specific (i.e., AIS and SRR), the discordance between police reported and the *hospital data* cases (under-reporting) narrows. However, there is still some discordance even for these more specific measures, indicating that some potentially very serious cases are not reported to police.

The road user profile for *police-reported and defined as 'hospitalised'* and the *police-reported attending hospital* were very similar. Within the police-reported serious injuries, the road user profile was different for the more specific definitions of serious injury (e.g., SRR and AIS), with a greater proportion of motorcyclists, cyclists, and pedestrians being included. This result shows that as the definition of serious injury becomes more precise (and potentially represents the 'most' serious cases) the vulnerable road users become more prominent. However, regardless of the definitions utilised the majority of police-reported serious injuries were drivers and passengers. In contrast, when all cases were considered, regardless of whether the injury was reported to police (i.e., hospital data cases), motorcyclists and cyclists together formed the majority of cases. This difference between police-reported and all hospital road crash injury cases likely reflects the under-reporting bias in police data. It has been shown in other studies that injuries involving these two road user groups are less likely to be reported to police (Alsop & Langley, 2001; Amoros, Martin, & Laumon, 2006; Boufous, Finch, Hayen, & Williamson, 2008; Langley, Dow, Stephenson, & Kypri, 2003; Watson, Watson, & Vallmuur, 2015). It is acknowledged however, that while only those coded as ‘traffic’ and/or without exclusion terms such as ‘off-road’ ‘track’ and ‘trail’ were included in the hospital data collections for comparison (i.e., most likely to compare to the definitions of on-road in the police data), this classification may not always be accurate. As a result, the under-reporting found in this study (and in others) may be over-estimated.

These results have major implications in terms of how serious injuries are identified for reporting purposes. Depending on the definitions and population used, the calculation of cost and understanding of the impact of serious injuries would vary greatly. It has been recommended previously that hospital data could be used to link with police data to gain a greater understanding of the serious injury problem. However, there has been little previous work conducted on understanding the inclusion criteria and definitions. This understanding is clearly required given the large discrepancies in the numbers and patterns of serious injuries arising from different definitions.

An important issue that should be noted relates to the mapping of ICD-10-AM coding to AIS and SRR. For SRR, the mapping corresponds directly to ICD-10-AM. However, the AIS mapping corresponds to ICD-10 and is then extrapolated to ICD-10-AM. The correspondence between ICD-10 and ICD-10-AM is at a level less specific, making mapping less precise. As a result the reliability of the assignment of AIS may be in question. In addition, for both AIS and SRR, there were still a number of cases in the *hospital data* that could not be assigned a value, while this was not a large proportion it may still be considered significant. Further research should be conducted to improve the current severity mapping practices. Also, status of ICD-11 should be monitored as this new coding system may better allow for mapping to these measures. A related limitation is the use of a single SRR rather than using multiple SRRs to form an International Classification of Diseases Based Injury Severity Score (ICISS). It was not possible to compute ICISS in this study as only one diagnosis was available in the EDIS and QISU data collections. While there has been some research suggesting that a single SRR may be just as useful as the multiplicative method (Henley & Harrison, 2009), this assumes the single diagnosis is the ‘worst injury’ that an injured person has sustained. It could be argued that the principal diagnosis could represent the ‘worst injury’; further examination of this issue with the current data may be the subject of future research. The other limitation relating to severity coding, concerns the use of ‘threat to life’ measures. Further research could examine the potential of other injury severity indicators (e.g., Disability Adjusted Life Years (DALYs), length of stay), to explore the impact of injuries not just in terms of ‘threat to life’, but also the impacts of disability and the burden on the health system.

While this program of research was conducted using Queensland data, the results do have international implications. The World Health Organisation (2010 has suggested conducting linkage studies periodically to assess police classification of injury severity against measures such as the Abbreviated Injury Scale (AIS). WHO (2010) also suggests applying a standard methodology to assess under-reporting of serious injuries in police data and apply conversion factors to police road crash injury data to provide a more accurate estimate.

It is possible that such a linkage could be restricted to police data and those collections that have the most relevance and/or are the most accurate (e.g., only QHAPDC for hospitalised injuries). Specifically, linkage with QHAPDC could be conducted more routinely to confirm the hospitalisation status of a police-reported road crash injury; this would be a good first step to improving serious injury reporting and would be consistent with current recommendations in Australia (The Parliament of Victoria Road Safety Committee, 2014). Ultimately, data linkage could potentially improve the reporting practices and epidemiological study in road safety. While it is unlikely that non-fatal injury data will ever be as accurate and reliable as fatal data; data linkage could be used to make substantial improvements.

This study has shown how data linkage can be used to investigate issues of data quality particularly in relation to defining serious injury. It has also demonstrated the potential improvements to the understanding of the road safety problem, particularly serious injury, by conducting data linkage. Even if linkage was not performed routinely, further research could be conducted to develop adjustments based on linked data, which could then be applied routinely to current reporting, for a more accurate representation of the serious road crash injury problem.

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Pedestrian self-reported exposure to distraction by smart phones while walking and crossing the road

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Abstract

Pedestrian crashes account for approximately 14% of road fatalities in Australia. Crossing the road, while a minor part of total walking, presents the highest crash risk because of potential interaction with motor vehicles. Crash risk is elevated by pedestrian illegal use of the road, which may be widespread (e.g. 20% of crossings at signalised intersections at a sample of sites, Brisbane) and enforcement is rare. Effective road crossing requires integration of multiple skills and judgements, any of which can be hindered by distraction. Observational studies suggest that pedestrians are increasingly likely to 'multitask', using mobile technology for entertainment and communication, elevating the risk of distraction while crossing. To investigate this, intercept interviews were conducted with a convenience sample of 211 pedestrians aged 18-65 years in Brisbane CBD. Self-reported frequency of using a smart phone for activities at two levels of distraction: cognitive only (voice calls); or cognitive and visual (text messages, internet access) while walking or crossing the road was collected. Results indicated that smart phone use for potentially distracting activities while walking and while crossing the road was high, especially among 18-30 year olds, who were significantly more likely than 31-44yo or 45-65yo to report smart phone use while crossing the road. For 18-30yo and the higher risk activity of crossing the road, 32% texted at high frequency levels and 27% used internet at high frequency levels. Risky levels of distracted crossing appear to be a growing safety issue for 18-30yo, with greater attention to appropriate interventions needed.

Introduction

Background

In Australia, pedestrians represent approximately 14% of road fatalities, accounting for 2,022 deaths in the ten years 2003-2012 (calculated from data reported in BITRE 2013). Pedestrians aged 75 and older have the highest fatality rate (between 1.7 and 3.4 times more likely than the next closest age group over the last 10 year period to 2014), followed by those aged 17-25 years (BITRE 2015). Crossing or walking along roads forms a minor part of total walking, but presents the highest risk because of the interaction with motor vehicles. As identified in the National Road Safety Strategy 2011-2020, pedestrians are an important vulnerable road user group, and represent, globally, 22% of all road deaths (WHO 2013). In addition to their relatively low mass (compared to motorised traffic), pedestrians are also rendered vulnerable by their inherent lack of protection in a crash. This is exacerbated by factors which increase the likelihood of pedestrian interaction with motorised traffic. For these reasons, pedestrian road use is regulated to some extent, and certain regulations that are protective of pedestrians also apply to drivers. However, illegal use of the road by pedestrians is widespread (e.g. 20% of crossings at signalised intersections at a sample of sites in Brisbane: King, Soole & Ghafourian 2009) and enforcement is rare for logistical reasons. In addition, most road crossing requires pedestrians to integrate visual and auditory information, make judgements of speed and driver intention, and decide when it is safe to cross within the constraints of their walking speed and ability to vary it. Even for pedestrians who can successfully integrate this information under normal circumstances, distraction (e.g. from technology) or temporary impairment (e.g. from alcohol) can interfere with the decision making process at a range of points –

pedestrians may fail to notice important auditory or visual information, or make incorrect judgements of speed (especially where multiple lanes or vehicles are involved), or incorrectly make an attribution of driver intention, or misjudge their own ability to get across in a given gap. Distraction and impairment therefore have the potential to exacerbate crash risk for pedestrians.

Mobile phone use is now commonplace in Australia, with increasing popularity among young people. A majority of young Australians (94%) aged 18-24 years use a mobile phone (Department of Broadband Communications and Digital Economy 2008). In 2012, almost a third (29%) of all children aged 5-14 years had a mobile phone. This number increases towards the upper age band, with 73% of 12-14 year olds shown to own a mobile phone (ABS 2013). Furthermore, mobile phones are increasingly the 'smart' type, with ownership in Australia estimated to sit at 81%, with 51% considering it their go-to device (Deloitte 2014). Smart phones enable pedestrians to not only use their mobile device for making voice calls and sending text message while they are 'on the move', but also to access the internet for email, social media and satellite navigation, as well as for their own personal music device. In their national survey of 802 teens aged 12-17 years, Madden, Lenhart, Duggan, Cortesi & Gasser (2013) showed that 74% of American teens aged 12-17 reported accessing the internet on mobile phones, tablets, and other mobile devices at least 'occasionally'. One in four teens are "mobile-mostly" internet users and older girls are especially likely to report this (34% compared to 24% of boys).

Pedestrian distraction from hand-held technological devices

Given the increase in popularity of smart phones, it is unsurprising that the prevalence of pedestrian distraction by hand held technological devices appears to be increasing, with studies showing that up to 40% of observed pedestrians are distracted when crossing the road (Ferguson, Green & Rosenthal, 2013; Thompson, Rivara, Ayyagari & Ebel, 2013; Bungum, Day & Henry, 2005). Mobile phone use while crossing the road and mobile phone-related injuries has been found to be higher for people under the age of 31 years (Nasar & Troyer, 2013; Nieuwesteeg & McIntyre, 2010) and particularly high among teens (Ferguson et al 2013). A US report recently published by Safe Kids Worldwide examined teens' walking behaviours. Over 34,000 students were observed crossing roads in front of schools and over 2,400 students participated in discussion groups. Twenty percent of high school students and twelve percent of middle school students were observed crossing the street while distracted. Students were most often texting on a phone (39%), or using headphones (39%). A further 20% were talking on their mobile phone. Girls were 1.2 times more likely than boys to be walking while distracted, with 17% of girls and 14% of boys observed as distracted by the devices they were using. The odds of being distracted were found to be 26% higher if there was a traffic light present, suggesting that teens may be more willing to use smart phone technology when they perceive their surroundings to be safe (Ferguson et al 2013).

Previous research has suggested that distraction can be of different types with differing levels of influence over ability to carry out driving or pedestrian tasks (Stavrinos, Byington & Schwebel 2009). Pedestrians distracted by mobile phones may be at increased risk of collisions with results showing that mobile phone users walk more slowly, change directions more frequently, are less likely to acknowledge other people, look left and right fewer times, are less likely to look at traffic before starting to cross, and make more errors than pedestrians who are not distracted (Thompson et al 2013; Bungum et al 2005; Hatfield & Murphy 2007). The effect of personal music devices on pedestrian behaviour has also been investigated with results suggesting that listening to music with headphones represents a different type of distraction from that of using a mobile phone (Walker, Lanthier, Risko & Kingstone 2012). The effect of mobile phone internet use on pedestrian injury has also received some attention. Byington and Schwebel (2013), for example, investigated crossing behaviour while accessing the internet on a phone among 92 college students. In a virtual environment, participants crossed a street 20 times, half the time while undistracted and half the time while conducting a mobile internet task. When distracted, participants waited longer to cross the street, missed more safe opportunities to cross, took longer to initiate crossing when a safe gap was available, looked left and right less often, spent more time looking away from the road and were more likely to be hit or almost hit by an oncoming vehicle. Furthermore, participants reported using mobile internet with great frequency in daily life, including while crossing the road. These results are particularly relevant as analyses controlled for gender, age, ethnicity, and pedestrian and mobile internet experience.

With the growth in use of mobile technology for entertainment and communication, pedestrians are increasingly likely to 'multitask' while walking, elevating the risk of distraction during road use. This area of pedestrian distraction is not well researched, though there are studies emerging in relation to crash outcomes (whether pedestrians who were distracted by mobile phones have a higher risk) (Thompson et al 2013; Bungum et al 2005; Hatfield & Murphy 2007) and several observational studies have been published (Ferguson et al 2013; Thompson et al 2013; Bungum et al 2005). The current research aimed to estimate the extent to which pedestrians are exposed to potential crash risk as a result of using technology.

Method

Prior to the design of the intercept interview questions, the potential sources of pedestrian distraction were identified as audio, visual, cognitive, physical, or combinations of these. Audio distraction from listening to music while walking or crossing represents audio-only distraction and is thus of a different order from that presented by using a smart phone to carry out more complex activities such as voice calls (cognitive + audio) or text messaging (cognitive + visual + physical). To keep the interviews brief, the questions focussed on only three of the potentially distracting activities: cognitive only (operationalised as using a smart phone for voice calls); and cognitive plus visual (operationalised as using a smart phone for text messages or internet access) while walking or crossing the road. To examine whether there were differences in pedestrian exposure to types of interaction, three interactions were distinguished: initiate, monitor, respond to, for the different activities. Data was collected in relation to both walking and crossing behaviour. An additional item in relation to audio-only device use (with headphones) was also asked. Several items relating to walking after having consumed alcohol were also included but are not reported in this paper.

A convenience sample of pedestrian commuters was sought. Intercept interviews were chosen in order to capture information directly from people about their typical behaviour (exposure) in relation to smart phones/MP3 players while walking and crossing and the types of activities that they typically engaged in.

Participation was anonymous and intercept interviews took place on week days between 8am and 5pm during the first week of November 2014. The research was approved by the Queensland University of Technology Human Research Ethics Committee (Approval number 1500000210).

Procedure

Two sites at which to approach pedestrians were selected from the five Brisbane city centre intersections with the highest pedestrian crash numbers (identified using Queensland Government Web Crash online database for 2001 and 2013). Selection was further based on high pedestrian volume and considerations of safety for the research personnel and potential participants (presence of signals and wide footpaths).

Four experienced Research Officers worked in pairs at the selected intersections (corner of Albert and Elizabeth Streets; corner of Edward and Ann Streets). Interviewers were instructed to invite participation from all pedestrians who appeared to be between the ages of 17 and 65 years, regardless of whether they were using a mobile phone or MP3 player at the time. This age range was chosen in order to focus on those most likely to be influenced by the use of technology (and older pedestrians are influenced by additional factors associated with ageing). Adolescents were excluded from the study for ethical reasons. A screening criterion was that participants had to own a smart phone. Only a few people were ineligible on this basis. Response rates were not calculated as refusal using this type of data collection method typically involves active avoidance of any contact with the researchers and therefore it cannot be determined whether everyone who passes the interviewer understands the purpose of the study (rather than, say, mistaking the approach for an attempt at marketing, sales or begging activity).

Interviewers administered the survey verbally, noting the responses on response proforma. Visual displays of the response options were used to assist participants in answering. Interviews were approximately 10 minutes in duration. Participants were offered a $5 Coffee Club voucher in acknowledgement of their time.

Results

Demographics

Responses were obtained from a convenience sample of 211 pedestrians (53% women) aged 17-65 years (mean 32 years, SD = 13.6). Of these, over half were aged 17-30 years (56%), with a further 23% aged 31-44 years as might be expected given the choice of location for recruitment (central business district of a metropolitan city). The majority indicated that they were employed (full time 45%; part time 17%), while 22% were students and 12% neither employed nor studying. Purpose of trip was primarily going to or from work (25%) or study (19%), with a further 25% shopping (31% 'other').

Almost half of the participants (47%) used public transport at least once a day, and 25% reported using public transport several times a week, suggesting the sample was commuter-based. Average time spent walking for transport or on a public roadway was high, equivalent to 3 ½ hours per week, with 30% of the sample walking 60-120 minutes per week, and 23% walking 2 ½ to 7 hours per week. Only 22 % walked less than 60 minutes per week. Most of the sample (79%) reported crossing a road while walking for transport at least 10 times per week, and a further 9% crossed 6-10 roads each week while walking for transport.

Smart phone use while walking and crossing the road

Table 1 displays the questions, response options and proportions of the sample giving each response. Examining walking first, overall use of smart phones while walking was high, with 28-50% of the pedestrians indicating that they used their smart phones for one or more of the activities at least daily (responses of 'more than once per day' or 'once per day'). A further 11-25% did so several times per week. Thus 43-65% responded 'several times per week', 'once per day' or 'more than once per day' to the activities. Monitoring or responding to the internet while walking appeared to be less common activities, with 48% and 43% respectively giving responses of 'several times per week', 'once per day' or 'more than once per day'. It is notable that for each of the text, internet and voice call activities there were around 20% of the sample who said they 'never' did this while walking (see Table 1).

For crossing the road, the proportion of pedestrians giving the higher use responses was much lower. Proportions of the sample who 'never' used their smart phones while crossing ranged from 50% (answering a call) up to 72% (monitoring internet). However, around 16% indicated they used their smart phones for texting activities (initiate, monitor, respond to) or voice calls (initiate, answer) while crossing (that is, responses of 'more than once per day' or 'once per day'). A somewhat lower proportion, 12%, used their phones for internet access activities (initiate, monitor, respond) on a daily basis while crossing the road. Use of audio-only devices was more widespread and more frequent, with almost 30% of the sample using these at least daily while crossing.

Table 1: Proportions of pedestrians who use their smart phones while crossing the road by activity and frequency (self-report)

Question wording and target activity

Walking How often do you use your smart phone to…. while walking	More than once per day (%)	Once a day (%)	Several times a week (%)	Once a week or less (%)	Never (%)
Initiate a text	33.2	9.0	15.6	16.1	26.1
Monitor text messages	42.7	9.5	16.1	10.9	20.9
Respond to a text	31.8	6.4	15.0	14.7	29.9
Initiate a call	24.8	8.1	19.5	26.2	21.4
Answer a call	26.5	9.0	24.6	23.7	16.1
Initiate an internet search or interaction	24.6	6.6	14.7	10.9	43.1
Monitor internet (e.g. Facebook)	24.2	7.6	14.7	8.5	45.0
Respond to internet (e.g. email)	19.9	7.6	15.2	8.5	48.8
Use an audio-only device to listen to music/radio with earphones/buds	29.4	2.8	11.4	4.7	51.7
Crossing How often do you use your smart phone to…. while crossing a road?	More than once per day (%)	Once a day (%)	Several times a week (%)	Once a week or less (%)	Never (%)
Initiate a text	9.5	6.2	5.7	9.0	69.7
Monitor text messages	13.3	6.2	9.0	9.5	61.9
Respond to a text	11.4	4.8	6.7	8.6	68.6
Initiate a call	11.4	4.8	4.8	18.1	61.0
Answer a call	13.3	8.6	10.0	17.6	50.5
Initiate an internet search or interaction	9.5	4.7	5.2	11.8	68.7
Monitor internet (e.g. Facebook)	8.5	4.3	6.2	10.4	70.6
Respond to internet (e.g. email)	7.6	4.8	6.2	9.0	72.4
Use an audio-only device to listen to music/radio with earphones/buds	26.1	3.3	9.5	3.8	57.3

Age group and exposure in relation to smart phone use while walking and crossing the road

Participants were grouped according to three age categories: 18-30 years (n = 118); 31-44 years (n = 48); and 45-65 years (n = 44) (total n = 210 for which age was stated). Two categories of exposure for smart phone use were distinguished: High exposure – responses of 'more than once per day', 'once per day' and 'once per week'; Low exposure – responses of 'less than once per week' or 'never'. The inclusion of 'several times per week' in the high exposure category was based on the patterns of distribution in the responses: individuals giving these responses to some activities were more likely to give high frequency of use responses to the other behaviours than to give the lower frequency responses (that is 'once per week or less' or 'never'). When categorised according to age and frequency of the behaviour, it was clear that pedestrians aged 30 years or under reported the greatest engagement in each type of smart phone use while walking and while crossing, with the exception of audio-only devices. Table 2 displays the responses to the walking items, and Table 3 responses to the crossing items according to age and exposure category.

Table 2: Walking while using a smart phone by level of exposure and age group

	Age group					
	18-30 (N=118)		31-44 (N=48)		45-65 (N=44)	
	Low exposure	High exposure	Low exposure	High exposure	Low exposure	High exposure
	(% of age group)	(% of age group)	(% of age group)	(% of age group)	(% of age group)	(% of age group)
Question **How often do you use your smart phone to…while walking?**						
Initiate a text	23.7	76.3	50	50	81.8	18.2
Monitor text messages	16.9	83.1	62.5	37.5	63.6	36.4
Respond to a text	27.1	72.9	47.9	52.1	81.8	18.2
Initiate a call	38.1	61.9	51.1	48.9	72.7	27.3
Answer a call	27.1	72.9	52.1	47.9	65.9	34.1
Initiate an internet search or interaction	38.1	61.9	37.5	62.5	86.4	13.6
Monitor internet (e.g. Facebook)	35.6	64.4	35.4	64.6	88.6	11.4
Respond to internet (e.g. email)	40.7	59.3	31.3	68.8	88.6	11.4
Use an audio-only device to listen to music/radio with earphones/buds	40.7	59.3	35.4	64.6	90.9	9.1

Two separate two-way analyses of variance (ANOVA; age group, 3 levels; gender, 2 levels) were carried out in order to determine if the differences in reported behaviours for the different age groups were statistically significant, and whether there were differences between men and women (overall or in the specific age groups). Total exposure to distraction while walking or crossing was deemed to be the sum of responses to all questions (nine items in Table 2 and nine items in Table 3). Mean scores for each person were used as an average of each person's exposure to distracted walking or crossing respectively. Responses were given on a 5-point scale: more than once a day, once a day, several times a week, once per week or less and never (low scores indicate responses equivalent to *more* frequent use). In addition, we reasoned that use of headphones only (for listening to music) might represent a lower level of risk when walking because it provides an auditory only distraction.. To examine this, a second mean score was calculated, excluding the audio only item (eight items). Mean score for responses to walking or crossing items, respectively (with and without the audio only item), were the dependent variables.

Walking.

A main effect of age group only was found for mean responses to the full set of items on use of smart phones while walking (i.e. including audio-only) $F(5, 203) = 18.064$, $p < .001$, $\eta^2(adj) = .291$, suggesting a large sized effect. There was no significant main effect of gender, nor a significant interaction effect for age group by gender. Post hoc testing (Tukey) revealed that pedestrians aged 18-30 years (M = 2.66; SD = 1.05) were significantly more likely than the 31-44 year olds (M=3.34, SD = 1.22) to indicate that they walked while using their smart phones ($p < .001$). The 31-44 year olds were in turn significantly more likely than the 45-65 year olds (M = 4.29, SD = .74) to report doing so ($p < .001$).

Similarly, excluding the item for walking while using audio-only, a main effect of age was detected for mean responses to use of smart phones while walking $F(5, 203) = 15.299$, $p <.001$, η^2 (adj) = .256, which is a large sized effect. There was no significant main effect of gender, nor a significant interaction effect for age group by gender. Post hoc testing (Tukey) revealed that pedestrians aged 18-30 years (M = 2.63; SD = 1.13) were significantly more likely than the 31-44 year olds (M = 3.29, SD = 1.38) to indicate that they walked while using their smart phones ($p < .01$). The 31-44 year olds were in turn significantly more likely than the 45-65 year olds (M = 4.24, SD = .79, $p < .001$) to report doing so.

Crossing.

Age-based differences were also evident for smart phone use while crossing the road. A main effect of age group only was found for mean responses to the full set of items on use of smart phones while crossing (including crossing with audio only) $F(5, 199) = 8.378$, $p < .001$, η^2 (adj) = .153, suggesting a large sized effect. There was no significant main effect of gender, nor a significant interaction effect for age group by gender. Post hoc testing (Tukey) revealed that the pedestrians aged 18-30 years (M = 3.77; SD = 1.14) were significantly more likely than either the 31-44 years (M = 4.26, SD = 1.01) ($p < .01$) or 45-65 years (M = 4.82, SD = .48) ($p < .001$) pedestrians to indicate that they crossed a road while using their smart phones. Although there was also a difference between the mean responses for the 31-44 year olds and the 45-65 year olds at $p = .022$, Levine's test of equality of error variances was significant, suggesting that a more conservative significance level be used in this test, and thus this difference did not meet the more stringent 1% significance level.

Similarly, excluding the item for crossing while using audio only, a main effect of age only was detected for mean responses to use of smart phones while crossing $F(5, 199) = 6.518$, $p <.001$, η^2 (adj) = .119 suggesting a medium to large sized effect. Post hoc testing (Tukey) revealed that 18-30 year olds were significantly more likely to report using their smart phones while crossing (M = 3.84, SD = 1.14) than were either the 31-44 year olds (M = 4.30, SD 1.01) ($p < .05$) or the 45-65 year olds (M = 4.84, SD = 1.08) ($p < .001$). The difference between the two older age groups was not statistically significant ($p = .054$).

Discussion

It is encouraging that around one fifth of the pedestrians sampled reported that they 'never' text, use internet or voice call actions on their smart phone while walking, and there was a higher proportion who indicated this for crossing.

Proportions of the sample who indicated that they used their smart phones while crossing the road were much lower than for walking, and this result was found for all age-groups. This finding is encouraging to the extent that it suggests that there is some acknowledgment of the increased dangers that such use constitutes when attempting to cross the road as opposed to walking. However, excluding the voice call and audio-only activities, around 30% of the 18-30 year olds indicated they used their smart phones at least once per week for a cognitively and visually distracting activity (that is, texting or internet access) while crossing the road. Many of them did so daily or more often. Moreover, it appeared that those 18-30 year olds who reported engaging in one activity also tended to report that they engaged in most of the others too, suggesting a subgroup that crosses the road frequently while using a smart phone (higher exposure) and is also more distracted (more complex activity level). This finding is of concern given it suggests that almost one in three young adult pedestrians are at relatively high risk of a crash while crossing the road. These patterns potentially reflect age-group related familiarity and facility with smart phone technology. Given that it is 17-25 year olds who are at second highest risk of death as pedestrians (after older pedestrians, 75 years and over), (BITRE 2015), it appears that we may expect a rise in both absolute numbers and the proportion of pedestrians deaths that this age group represents.

Overall, the results of the intercept interviews suggest that there is a particular subgroup of pedestrians who should be targeted in interventions to address distracted crossing. These are the 18-30 year old, high frequency (characterised by high use of various activities on their phones) smart phone users. However, the research did not attempt to include adolescents in the sample. Since adolescents comprise a larger proportion of the pedestrian activity and are also more likely to both own and be high-frequency users of smart phones, we would expect that interventions should target this age group too.

Table 3: Crossing the road while using a smart phone by age group and level of exposure

	Age group					
	18-30 (N=118)		31-44 (N=48)		45-65 (N=44)	
	Low exposure	High exposure	Low exposure	High exposure	Low exposure	High exposure
Question	% of age group	% of age group	% of age group	% of age group	% of age group	% of age group
How often do you use your smart phone to…. while crossing?						
Initiate a text	70	30	81	19	98	2
Monitor text messages	61	39	77	23	93	7
Respond to a text	67	33	83	17	98	2
Initiate a call	71	29	81	19	98	2
Answer a call	58	42	72	28	91	9
Initiate an internet search or interaction	71	29	88	12	98	2
Monitor internet (e.g. Facebook)	73	27	88	12	96	4
Respond to internet (e.g. email)	73	27	88	12	96	4
Use an audio-only device to listen to music/radio with earphones/buds	48	52	69	31	91	9

Limitations

There are several important limitations to our study. Firstly, we cannot be certain that pedestrians in the sample interpreted our questions in relation to crossing to mean 'once you have stepped off the kerb' and so their reported frequency of using their smart phones while crossing may not be as high as we have reported. Participants gave no feedback, however, to suggest that they were unsure

as to whether we were asking about while they were waiting to cross or while they were actually in the roadway.
Since these were intercept interviews, participants could have asked for clarification from interviewers, and none did, so we assume here that they interpreted the questions as we had intended. Similarly, we did not ask participants to think specifically about crossing at a signalised crossing versus a non-signalised location (such as mid-block). It is possible that their use of smart phones may be affected by this in terms of whether they perceive the risk at one location to be higher than the other and whether they accommodate for it. This is an important direction for future work especially in survey form with larger samples.

A second limitation is the self-report method used, which is subject to potential bias from socially desirable responding or errors of recall. We are unable to determine the extent to which our results may have been affected by either of these biases. However, the interviews were carried out in places where pedestrians were likely to actually be engaged in smart phone use while walking or crossing the road, or where they might typically be doing so as part of their normal activity, so we would hope that this would be more likely to facilitate ready and accurate recall.

Finally, the study results are based on a relatively small sample drawn from Brisbane CBD, which may limit the generalizability of the results to other locations. As indicated above, there was no attempt to include adolescents in the sample, and this is potentially a very important age group of pedestrians. However, as described, locations for the interviews were carefully chosen based on evidence of pedestrian crashes, and therefore highly relevant locations for the purposes of the research. We have no reason to expect that pedestrian behaviour in other Australian or New Zealand cities is substantially different from Brisbane, and so would expect that the results can be useful when considering other city centres. However, we regard it as important that similar research be carried out for adolescent pedestrian behaviour in future studies.

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Understanding drivers' motivation to take a break when tired

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Abstract

Evidence shows that drivers are aware of and can report increasing fatigue while driving and most importantly can detect the likelihood of falling asleep prior to crashing. Drivers reporting high likelihood of falling asleep are around four times more likely to crash and nine times more likely to cross the centreline in a driving simulator. This shows that drivers can make an informed decision to drive or not drive when tired. The question is why drivers don't always make the safe choice when tired. The aim of the study was to investigate the impact of motivational factors on drivers' decision to respond or not to fatigue while driving. The study examined two motivational influences affecting fatigued drivers: the fear of fatigue-related crashes and the need to finish the trip in a specified time. The relative strength of influences was manipulated through monetary incentives. Three groups of 30 tired drivers did a two hour drive in a simulator in each of three conditions: Safety motivation - drivers were informed that an amount would be deducted from $100 whenever they had a serious safety incident; Time motivation - drivers were told that money would be deducted from their $100 if they were slower than expected; No motivation - drivers were paid $100 at the end of the trip regardless of safety or time. Preliminary results showed that Safety motivation was effective: many drivers took breaks and driving performance was improved compared to No motivation. Time motivation was also effective in making drivers take fewer breaks and complete the trip earlier.

Introduction

Driver fatigue is a recognised threat to road safety. Estimates of its involvement in fatal crashes go as high as 33%, but often tend be around half that (e.g., Tefft, 2012). A considerable amount of research has been conducted to identify and better understand risk factors for fatigue and related crashes but relatively little research has investigated factors that affect drivers' implementation of fatigue countermeasures. This issue is particularly important for professional drivers whose use of countermeasures might be shaped by commercial incentives and pressures that favour work over rest (e.g., Golob & Hensher, 1994; Hensher, Battellino, Gee, & Daniels, 1991; Quinlan & Wright, 2008) and for ordinary drivers who want to reach their destination as soon as possible. It is also important for public policy which makes assumptions about how successfully drivers can identify and react to fatigue and about the extent to which they can reasonably be held accountable for fatigue crashes (Fletcher, McCulloch, Baulk, & Dawson, 2005; Jones, Dorrian, & Rajaratnam, 2005).

There is mounting evidence that drivers are sufficiently aware of their own sleepiness and likelihood of falling asleep in the near future that they could decide to take action to avoid crashing (Reyner & Horne, 1998; Williamson, Friswell, Olivier, & Grzebieta, 2014) although it is less clear that drivers relate their sleepy state to crash likelihood (Williamson et al., 2014). In addition, Hockey's effort compensation theory (2012) predicts that tired drivers should be motivated to take breaks due to the increasing effort required to maintain performance when fatigued. However, the fact that fatigue crashes continue to occur raises questions about how effective motivational effects are on fatigued drivers and their decisions to break from driving. The current study investigated whether drivers could be motivated to increase break-taking in response to fatigue by providing incentives that favoured safe performance or incentives to favour trip completion over safety, compared to no incentives.

Method

Design

The experiment examined the effects of three motivational conditions (No, Safety or Time incentives). Drivers in all groups were told that they would receive $100 (in retail gift cards) at completion of a 201 km simulator drive. Safety group participants were told they would lose $20 from a maximum of $100 every time they drove off the road, crashed, or crossed the centreline, thus providing motivation to avoid fatigue driving errors. Time group participants were told they would lose $20 for every minute over 2 hours that they took to complete the drive, thus providing motivation not to stop even if fatigued. All groups received the same manipulation aimed to induce fatigue during the drive: a shortened sleep in the night before and testing in the mid-afternoon period and a monotonous drive scenario. Driving performance was indexed by the occurrence of adverse events (crashes, centreline crossings, lane departures and lane edge touches) and variability in lane position. Subjective ratings of sleepiness, the likelihood of falling asleep and of crashing in the following few minutes were measured regularly throughout the drive. The Optalert Drowsiness Management System measured objective blink indices of drowsiness using the proprietary Johns Drowsiness Score (JDS)

Participants

Ninety (n=90) people fully licenced to drive cars in NSW were recruited via electronic and actual noticeboards at UNSW. 63.3% were men and the mean age was 26.4 years (SD=8.05; range 20 to 60). Most (78.9%) had been licenced for less than 10 years and currently drove 77km per week on average (SD=83.85, range 0 to 500). Thirty people took part in each motivational condition and the distribution of age, sex, and driving experience was similar across conditions.

Materials and Procedure

Participants first attended a training session involving completing brief demographic and sleep questionnaires, a 60km practice drive on a desktop STISIM simulator and being fitted with Optalert glasses to record blink data. They were then instructed to reduce their hours in bed to five on the night before the test session by delaying bedtime but retaining usual waking time. Actigraphs (Respironics Actiwatch 2) and a brief sleep diary were provided to validate the sleep restriction.

On the next, test day, they completed a brief questionnaire about caffeine, alcohol and medication use, were fitted with the Optalert glasses and were reminded to drive according to the road rules. The Safety and Time condition participants were told of the incentive rules that would apply to their performance. All participants then rated their sleepiness, sleep likelihood and crash likelihood and commenced driving at 14:30. The drive scenario lasted 1:59 at the posted speed limits (80, 100, and 110 kph). The route was a monotonous, rural road. A trip odometer, digital clock and the rating scales were visible to participants during the drive. Verbal subjective ratings were prompted by a tone 35 times across the drive. At the end of the drive, participants again rated themselves and were debriefed. All participants received the full $100 value regardless of their performance.

The motivation groups were compared on sleepiness-related and driving performance variables using Chi square and ANOVA with $p<.05$ and Bonferroni corrected post-hoc tests.

Results

Success of fatigue manipulation

Actigraph data showed that participants fell asleep on average at approximately 2:35 and woke at approximately 7:05 am on the test day, achieving an average of 4:49 h sleep (Table 1). There were no significant differences between incentive conditions on any diary recorded sleep variables, including subjective ratings of quality and feeling refreshed on waking, nor on actigraph measures of sleep. Similarly, there were no significant differences between the motivation conditions in maximum rated sleepiness, maximum JDS measured during the drive, or percentages of people who fell asleep while they were driving (or at any time during the drive).

Table 1. Manipulation of sleepiness

	Control	Safety motivation	Completion motivation	All participants	p-values
Actual sleep hours measured by actigraph (Mean, SD)	M=4:43h, SD=1:00h	M=4:42h, SD=0:45h	M=4:54h, SD=0:56h	M=4:49h, SD=0:56h	$F_{2,86}$=.401, p=.671
Rated sleep quality (/100; Mean, SD) [a]	M=61.43, SD=24.44	M=54.93, SD=25.77	M=56.97, SD=21.52	M=57.78, SD=23.86	$F_{2,86}$=.577, p=.564
Refreshingness of sleep (/100; Mean, SD) [a]	M=33.9, SD=17.48	M=39.37, SD=22.91	M=46.33, SD=18.88	M=39.87, SD=20.32	$F_{2,86}$=2.945, p=.058
Hours since waking at start of drive (Mean, SD)	M=7:27:39, SD=1:23:11	M=7:30:38, SD=1:10:53	M=7:17:21, SD=1:30:38	M=7:25:11, SD=1:21:13	$F_{2,86}$=.216, p=.806
Highest KSS (/9) rating during drive (Mean, SD) [b]	M=7.63, SD=1.77	M=7.53, SD=1.61	M=7.50, SD=1.73	M=7.56, SD=1.69	$F_{2,86}$=.049, p=.952
Highest Optalert JDS score during drive (Mean, SD) [c]	M=3.21, SD=1.92	M=2.84, SD=1.43	M=3.24, SD=1.73	M=3.10, SD=1.70	$F_{2,86}$=.493, p=.613
Participants reported falling asleep during drive (%)	46.7	23.3	36.7	35.6	$X^2_{(2)}$=3.588, p=.189

[a] Higher ratings indicate better subjective sleep; [b] Higher ratings indicate greater subjective sleepiness; [c] Higher JDS indicates greater drowsiness

Driving performance

Table 2 compares the motivation conditions on measures of driving performance. There were significant differences between conditions in minutes taken to complete the drive and the percentage of drivers taking breaks. Consistent with their incentive instructions, post hoc comparisons confirmed the Time group took significantly less time to finish the drive than the No motivation condition, and were less likely than both the other conditions to stop during the drive. Post hoc tests showed the number and length of breaks was significantly lower in the Time group than in the No motivation group. Number of lane edge touches and variability of lane position both showed a significant effect of motivation condition. Post hoc tests confirmed that Safety motivation participants had fewer lane edge touches and less variability of lane position than No motivation drivers. The conditions did not differ significantly on any other measures of lane departure or the proportion of people who crashed although as this was low in all groups. This finding may be due to sample size limitations.

Table 2. Driving performance

	No motivation	Safety motivation	Time motivation	p values
Minutes to complete drive (Mean, SD)	122.31, 5.80	121.65, 7.86	118.28, 3.01	$F_{(2,87)}$=4.02, p=.02
Drivers who stopped (%)	36.7	40	6.7	$X^2_{(2)}$=10.08, p=.006
Number of stops (Mean, SD)	1.4, 2.3	1.0, 1.7	.1, .3	$F_{(2,87)}$=4.71, p=.01
Total time(s) stopped (Mean SD)	129.1, 295.3	40.9, 69.3	.2, .8	$F_{(2,87)}$=4.25, p=.02
Drivers who crashed (%)	16.7	6.7	10	$X^2_{(2)}$=1.58, p=.46
Drivers with centreline crossings (%)	13.3	3.3	6.7	$X^2_{(2)}$=2.17, p=.34
Number of lane edge touches across the drive (Mean, SD)	85.63, 101.87	29.80, 47.66	54.70, 71.15	$F_{(2,87)}$=3.98, p=.02
Variability of lane position across the drive (Mean, SD)	.45, .23	.32, .17	.38, .18	$F_{(2,87)}$=3.27, p=.04

Discussion

This analysis showed that providing safety-related incentives to respond to increasing fatigue meant that drivers were more likely to take breaks from driving than drivers provided incentives to complete the drive under time pressure. The Time incentive group, as expected, completed the trip faster with only a small minority stopping. The Safety incentive group produced the best driving performance overall. In contrast, the No motivation group, who were given no incentive instructions, showed poorest driving performance with more lane edge touches and greater lane variability than the Safety group.

Participants reached similar levels of fatigue in all study conditions. The sleep, sleepiness and drowsiness measures indicated that participants in the three groups were similarly affected by the sleep restriction protocol during the drive. The results suggest the simultaneous operation of two processes. First, the poor performance of the No motivation group suggests that any incentive can improve the driving performance of tired drivers in monotonous conditions. This explanation is consistent with findings of previous research on train driving showing that even small manipulations to reduce the monotony of the driving task markedly improved driving performance (Dunn & Williamson, 2012). Second, the finding that driving performance was best for the Safety incentive group suggests that this incentive encouraged more breaks from driving which would be expected to refresh the drivers and improve driving performance, at least in the short term. Further, in-depth analysis should reveal more about the relations between break-taking, driving performance and sleepiness under different incentive conditions.

Previous research suggests that despite being aware of the symptoms of fatigue and sleepiness before they fall asleep during driving, drivers underestimate the link between these symptoms and falling asleep and potentially overestimate their ability to overcome these symptoms (Nordbakke and Sagberg, 2007). There is also some evidence that individuals differ in their propensity to take a break from driving when sleepy. Characteristics like age, gender, motivation and risk perception (Watling, Armstrong, Obst and Smith, 2014) and more tolerant attitudes to driving while tired (Watling, 2014) have been linked with continuing to drive while sleepy. All of these studies involved self-report questions requiring drivers to recall instances when they have experienced fatigue or fallen asleep at the wheel. The strengths of the current study are that it manipulated motivators to take breaks from driving or not and investigated actual driving behaviour when drivers were experiencing fatigue. The results indicate that incentives to manage fatigue were effective in improving driver performance.

Overall, these results suggest that providing incentives to drivers to modify their driving behaviour can be effective. Drivers will take breaks from driving if provided a motivation to do so. On the other hand, however, drivers motivated to ‘push on’ and reach their destination quickly will also do so. Clearly, our attempts to reduce driver fatigue must develop strategies that highlight and increase drivers’ motivation to take breaks strategically in response to their fatigue state. This is especially important for professional and long distance drivers who already face incentives that favour continuing to drive rather than taking breaks to manage fatigue.

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The Australian Naturalistic Driving Study: from beginnings to launch

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Abstract

The Australian Naturalistic Driving Study (ANDS), a ground-breaking study of Australian driver behaviour and performance, was officially launched on April 21st, 2015 at UNSW. The ANDS project will provide a realistic perspective on the causes of vehicle crashes and near miss crash events, along with the roles speeding, distraction and other factors have on such events. A total of 360 volunteer drivers across NSW and Victoria - 180 in NSW and 180 in Victoria - will be monitored by a Data Acquisition System (DAS) recording continuously for 4 months their driving behaviour using a suite of cameras and sensors. Participants' driving behaviour (e.g. gaze), the behaviour of their vehicle (e.g. speed, lane position) and the behaviour of other road users with whom they interact in normal and safety-critical situations will be recorded. Planning of the ANDS commenced over two years ago in June 2013 when the Multi-Institutional Agreement for a grant supporting the equipment purchase and assembly phase was signed by parties involved in this large scale $4 million study (5 university accident research centres, 3 government regulators, 2 third party insurers and 2 industry partners). The program's second development phase commenced a year later in June 2014 after a second grant was awarded. This paper presents an insider's view into that two year process leading up to the launch, and outlines issues that arose in the set-up phase of the study and how these were addressed. This information will be useful to other organisations considering setting up an NDS.

Background

Naturalistic driving studies (NDS) are one of the most exciting developments in road safety in recent years. In an NDS, volunteer participants drive an instrumented vehicle (usually their own) fitted with an unobtrusive Data Acquisition System (DAS) for a period of months. The system continuously records their driving behaviour (e.g. where they are looking), the behaviour of their vehicle (e.g. speed, lane position) and the behaviour of other road users with whom they interact (e.g. other drivers, motorcyclists, cyclists and pedestrians). When the first 100-car study conducted by Virginia Tech Transportation Institute (VTTI) was made public, the excitement about the possibilities that had opened up was palpable (Dingus et al, 2006). There was general consensus that studying 'natural' driving would provide a range of new insights into how drivers manage the demands of driving in the real world.

Traditionally, road safety has focussed on crashes and fatalities, derived primarily from crash data collected by police, in-depth crash investigations, Coroners' and hospital data and from data from surveys on driver exposures to risk as this has been the best available data. These data sources are severely limited in the depth and quality of 'real-world' information they provide about driver and road user behaviour and performance, which are primary contributing factors in most collisions (Antin et al, 2011). Furthermore causal characteristics can often only be inferred, if at all, from available evidence after a crash or from surveys with confounding from unknown self-reported biases (Gordon and Regan, 2013). Existing data collection methods rely on the limited post-crash accuracy and biases of driver and witness recall of events and on retrospective physical evidence from crash scenes - with little or no pre-crash information about other vehicles and road users involved. Naturalistic driving studies provide the opportunity to study what drivers do and how they handle the broad range of components of the road system: their vehicle, the road, road infrastructure and road regulations. These studies also open up new opportunities for understanding how drivers interact with these various components, how they deal with hazards of driving and the conditions in which risky driving occurs as well as how drivers adapt to risky driving situations and, most importantly, about how drivers avoid crashes.

The development of the Australian Naturalistic Driving Study

The first large scale NDSs were conducted in the USA. Australia was not far behind. Currently naturalistic driving studies are being conducted in Canada, China and the EU. In Australia, the impetus was taken by a consortium of university researchers, who combined with road safety authorities, partners and organisations to develop a proposal to conduct a naturalistic study in Australia. One of the main reasons these studies are occurring at this time is that the technology is emerging that can collect the data about the driver, vehicle and environment that are needed, and that can store and analyse the enormous amount of data generated. However, these studies are expensive. The consortium was successful in attracting Australian Research Council funding, first for the equipment, and then for conducting the project, in partnership with funding from road authorities, industry partners and universities.

With studies springing up all over the world now, it is reasonable to ask: why do we need one in Australia? Primarily, it is because our driving conditions, environment, composition of our vehicle fleet and driving regulations and culture are different from other parts of the world. A considerable number of studies have shown that country and even regional differences like population density (Eksler et al, 2008), structure and culture (Wegman and Oppe, 2010) and socioeconomic factors (Hollo, et al., 2010) play a role in road safety outcomes. Furthermore, while previous NDS projects have yielded some valuable insights into driver and road user behaviour in general, their applicability to the Australian context is questionable for several reasons. First, they have not yet explored many of the high priority, and intractable, road safety problems identified in the Australian National Road Safety Strategy (ATC, 2011). Speed choice and vulnerable road user interactions, in different situations, and in urban versus regional areas, are good examples (ATC, 2011). Second, it is not clear how well the findings translate to Australian conditions. Differences in cultural and societal norms, road laws, enforcement, vehicle fleets, road environments, distances travelled, environmental conditions and mix of road users may threaten the transferability of data across countries.

Developing the Australian Naturalistic Driving Study (ANDS) has involved researchers from four Australian universities (TARS Research at UNSW, MUARC at Monash University, CASR at Adelaide and CARRS-Q at QUT), representatives of road authorities (Centre for Road Safety in NSW, VicRoads and Office of Road Safety at Main Roads Western Australia) and insurers (Transport Accident Commission or TAC in Victoria, Motor Accident Commissions or MAC in South Australia) as well as the National Roads and Motorist Association (NRMA). Recently Hyundai and Seeing Machines have joined the consortium. Much of the initial discussions were about the best approaches to large-scale instrumentation of vehicles. After weighing up many options, it was decided to purchase the Data Acquisition Systems (DAS) developed by Virginia

Tech Transport Institute (VTTI). This decision was based on the following: VTTI had the most experience with studies similar to the one planned for Australia, their DAS was judged at the time to be the most capable for the price and readily available for installation and, most importantly, they had extensive expertise in analysis of the large datasets that are generated by the video and sensor equipment installed in each vehicle.

The final design of the ANDS project involves recruitment of 360 volunteer drivers (180 from New South Wales and 180 from Victoria) who will have their private vehicle equipped with the instrumentation for 4 months. The system silently records each participant's driving behaviour (e.g. where they are looking; engagement with secondary tasks), the behaviour of their vehicle (e.g. speed, lane position) and the behaviour of other road users with whom they interact (e.g. other drivers, motorcyclists, cyclists and pedestrians) in normal and safety-critical situations. Each data collection system incorporates multiple sensors (video cameras, a still camera, GPS, radar, accelerometers, etc.) to provide a complete picture of driver, vehicle and road user behaviour in all driving situations they encounter.

The ANDS differs from previous naturalistic studies in other countries in a number of ways. These differences include:

Vehicles will be instrumented for a shorter period: As in all naturalistic studies, drivers will have their own car instrumented with data recording equipment, allowing continuous recording of the participating drivers' behaviour and those of others with whom they interact. However, unlike other studies that instrument each vehicle for 12 months, in the ANDS each vehicle is instrumented for 4 months. This has the benefit of increasing the number of drivers and vehicles that can be included in the study. However, instead of studying 100 driver/vehicles for 12 months, ANDS is recruiting 360 driver/vehicles for 4 months. Longer study periods for each driver are needed in northern hemisphere studies because many locations have major seasonal fluctuations in weather (e.g. snow) over the year that must be controlled by studying each driver across all seasonal challenges. In most parts of Australia, major weather fluctuations are not an issue. Moreover, by increasing the number of participants, the ANDS is likely to detect more safety critical events, e.g. near misses and crashes. Evidence from the 100-car NDS in the US (Klauer et al., 2006A) found individual differences in the likelihood of crashing with 35 percent of drivers having at least one crash and 14 percent accounting for around half of all crashes. By increasing the number of drivers in the study, the ANDS study may pick up a larger sample of crashes: the least frequent safety critical event. Less severe safety incidents occurred very frequently in the 100-car study with 761 near crashes and 8,295 safety incidents over 12 months so they are expected to be common in the ANDS as well.

The driver sample will be experienced drivers: The ANDS is recruiting to the study only drivers who have a full driver's licence in the 20 to 70 years age range. Many other naturalistic studies have recruited drivers from across the age range, including novices. While understanding the driving behaviour of novice drivers is of great importance to road safety, the ANDS took the view that the sample size in the Australian study was too small to allow for study of small subgroups. The issue of novice driving will be explored in subsequent naturalistic driving studies in Australia in which this driver group is the primary focus.

Expanded vehicle/driver monitoring: The ANDS has taken the opportunity to increase the scope of driver and vehicle monitoring by including additional technologies, ones that both look outwards to the external environment (Mobileye) and inwards toward the driver (Seeing Machines).

The Mobileye is a camera-based Advanced Driver Assistance System (ADAS) and will be installed in all vehicles. It includes a "smart" forward facing camera which, along with proprietary algorithms, under normal operations provides the driver with alerts when the system detects that the driver is (a) likely to collide with a vulnerable road user (pedestrian, bicyclist or motorcyclist), (b) likely to collide with a forward obstacle (e.g. car), (c) following a vehicle ahead too closely, and (d) likely to drive off the road (e.g. if drowsy). In this study, the system will not be used to provide warnings; rather, it will be used as a sensor input additional to the DAS units. This will provide: (i) an additional automated trigger for detecting in the data recorded by the DAS units potential collisions, especially with vulnerable road users; and (ii) a validation test of the accuracy of algorithms contained in the VTTI DAS units for detecting near-crashes and other safety-critical events. In future NDS studies, Mobileye can be used as both a sensor and as an ADAS system, to understand driver interaction with the system in normal and safety-critical situations.

Real time driver monitoring: The ANDS aims to examine driver states including distraction, inattention, and drowsiness. Examination of these states benefits greatly from an analysis of features including driver head orientation and gaze direction. Assessment of such driver states in research studies has historically been a significant challenge primarily because the analysis of these states has been largely reliant on the post-hoc analysis of video data. While this approach has been fruitful, it necessarily constrains the type of measures that can be collected (via video extraction), while also involving hundreds of hours of manual video coding prior to any data analysis.

A key point of difference with the ANDS is the inclusion of real-time driver monitoring within a subset of the participant vehicles. Real-time driver monitoring offers a number of potential advantages with respect to supporting the collection of a wide range of driver features while also potentially removing the need for hundreds of hours of video analysis. The driver monitoring system (DMS) by Seeing Machines is being included in the ANDS and monitors driver attention state during normal and automated driving. For the purposes of the ANDS, the DMS classifies a driver's direction of attention through a real-time analysis of head pose, gaze and pupil metrics and eyelid opening. The system monitors whether a driver's attention is directed toward the forward roadway, off the road, or inside the vehicle cabin such as on the centre console or the driver's lap, and whether the driver is in a drowsy state. This technology can support a range of research questions including those related to: distraction and behaviour when drivers are, for example, interacting with a centre console or using a mobile phone; drowsiness and the driver behaviours evident in the lead-up to drowsiness events; head-checking behaviour at intersections and during lane changes; and examination of gaze patterns to better understand the impact of driver experience and impairment on driver attention.

Issues encountered in developing the ANDS: getting to launch

The ANDS project was formally launched on 21st April, 2015. Over the two year period between the initial award of funding from the Australian Research Council and the project launch, the Consortium faced a large number of challenges. In most cases, 'if we had known' beforehand, the path to the commencement of the project would have been significantly smoother. It is worthwhile, therefore to document some of these issues so that others may be spared similar problems.

Legal issues: A study that involves video recording of driver behaviour and modifications to participants' vehicles raises a large number of potential issues. A primary concern is the issue of how to handle illegal driving behaviours or crashes involving our participating vehicles that are caught on video. Legal advice was that if serious traffic offences are detected when going through video analysis, they would need to be reported to relevant authorities but that this should be done on a case-by-case basis. Given the very large amount of data that is being collected in ANDS, this is likely to be a very rare occurrence. The question of insurance was also a concern. Again, legal advice was that any installation damage or damage to study equipment was covered by the research institution. Participating vehicles needed to be insured but did not require comprehensive insurance. The Consortium also sought confirmation that the DAS and other equipment installed in participants' vehicles were within legal requirements by obtaining an Australian Design Rules Engineer Signatory Certificate. All vehicles also carry an official letter detailing the purpose and nature of involvement in the study that can be provided to insurers to confirm this information should the need arise.

Ethics: A large amount of time and resources were invested to ensure that the project met all ethics clearance requirements to commence. The ANDS project has avoided a number of potential ethical issues by only recruiting volunteer participants, and by ensuring that they are fully informed about all aspects of the study, the implications of their participation and that they can withdraw from the study at any time. A significant potential ethical issue that caused a number of concerns relating to privacy was that the person driving the instrumented vehicle was readily identifiable on video. This problem has been solved by pixelation of driver obscuring faces in all images that will be shown publically and ensuring that analysis of video data is conducted by researchers who have signed confidentiality agreements and under conditions in which only authorised researchers have access to the video material.

Attempting to use technology built for US roads: A problem that was recognised early, but which caused considerable delay was the necessity for VTTI to adapt their DAS units to driving on the left hand side of the road and wanting multiple cameras at different angles. This resulted in significant delays in supply of the equipment to Australia and the commencement of the study.

Logistical issues: Instrumentation of large numbers of vehicles over the minimum time presents significant logistical issues. First, it is essential to find staff with appropriate skills and expertise to tackle the problem of installing complex technologies into a very wide range of different types of vehicles without overtly indicating that the vehicle had been instrumented. As these studies become more common, there will be a cohort of people with technical expertise available. The solution for ANDS was to hire a highly skilled technical officer to oversee the installation (and de-installation) part of the project and embark on a significant training program for all other staff. Second, finding suitable installation/de-installation sites were also an issue as a large undercover space and security for tools and instruments is required as well as an environment for interviewing drivers. Unlike the Monash University site there was no suitable space on the UNSW campus. With a great deal of assistance from the Centre for Road Safety this problem was overcome in NSW through the provision of an off-campus facility. Third, it is important the instrumentation requires no more than a single day to install in order to present as little inconvenience for the volunteer drivers as possible. The average time of an install is about 7 hours for the ANDS system.

Recruitment of participants: Feedback from VTTI researchers was that they had experienced considerable difficulty recruiting volunteers, especially amongst younger drivers. The ANDS Consortium put significant effort into designing a recruitment strategy to publicise the study as widely as possible. It was clearly successful as the first wave of instrumentation of vehicles was fully subscribed within a few weeks of the study launch and participants are now on the waiting list for full sample.

A screening questionnaire was set up on the study website to assess key selection criteria including number of trips driven per week, type of vehicle, and city/region of residence. By the end of July 2015, the study received 1,071 expressions of interest through completion of this questionnaire, with 663 potential participants satisfying all key selection criteria (309 in NSW, and 354 in Victoria). This sample included a relatively even spread of males (55%) and females (45%), similar numbers in the defined age groups (20-35 years (28%); 36-50 years (33%); 51-70 years (39%)), and contained mainly sedans (34%), hatchbacks (32%), and four-wheel drives/SUVs (24%). All potential participants drove at least 10 to 14 trips per week (for example, driving one way from home to work is considered to be one trip). In New South Wales, the most successful recruitment modes so far have been targeting drivers through the National Roads and Motorist Association (NRMA) Open Road magazine and NRMA social media platforms such as Facebook and Twitter. In Victoria, the study flyer sent out with vehicle registration renewal notices by VicRoads attracted the most attention.

By the end of July 2015, twenty-four (24) participant vehicles have been instrumented at the NSW site. There were equal numbers of male and female drivers and of the youngest and oldest driver age groups (38% aged 20-35 years, 38% aged 51-70 years; as well as 25% aged 36-50 years), drivers from Sydney metropolitan areas (75%) compared to regional NSW (25%), and mostly hatchback vehicles (41.7%). Makes of participant vehicles include SsangYong, Kia, Mazda, Hyundai, Toyota, Holden, Nissan, Ford, Mitsubishi, Subaru, and Volkswagen.

So much data and so many research questions: Naturalistic driving studies can potentially answer an enormous range of research questions, but often do not have the resources to do so. The ANDS project proposal laid out seven key research themes, which were selected through consultation with all researchers and participating organisations. Details of their selection were described in Regan et al. (2012 and 2013). In brief, the themes selected were:

- Safety at intersections
- Speed choice
- Interactions with vulnerable road users
- Fatigue
- Distraction and inattention
- Crashes and near-crashes
- Interactions with intelligent transport systems (ITS)

Designing and completing the analysis of the voluminous data available from the ANDS study is likely to be a work-in-progress over the next decade or more. On the one hand, this is one of the most exciting aspects of these studies, but it is also a potential problem. The ANDS study is controlling the problem by establishing an active data analysis group whose task is to investigate strategic approaches to analysis, including automation of the identification of target incidents and driver behaviours. The study will also be using the various technologies (DMS, Mobileye, etc.) as triggers to identify behaviours / events of interest. It is also delegating the analysis task for specific themes to members of the Consortium with expertise in each area and setting up analysis groups for each theme. An important part of this aspect of the project will be seeking additional resources for data analysis, researchers and partners from outside this Consortium to collaborate on analysis and publication of findings.

The next steps

All of these issues have been overcome sufficiently for the project to commence and to be now progressing exceptionally well towards fulfilling its original aims of providing Australia with answers to some intractable, high priority, road safety problems that cannot be solved using currently available methods; creating a new, national, capability for collecting and analysing previously unavailable data and setting up a permanent Australian database that can be added to by future studies and become a public resources that no single university or transport safety authority in Australia on its own could afford; and supporting applied and investigator-driven research. Our ANDS project, unlike previous large-scale NDS projects that have focussed on the detection and characterisation of crashes and near-crashes, will tell us how people drive normally to avoid crashes and minimise risk, and how they modify their behaviour to adapt to conditions of increased crash risk (e.g. when fatigued, distracted, when speeding, in the vicinity of other road users, etc.).

Acknowledgements

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An innovative online intervention: The Steering Clear First Offender Drink Driving Program

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Abstract

Drink driving remains a substantial public health issue warranting investigation. First offender drink drivers are seen to be less risky than repeat offenders, though the majority of first offenders report drink driving prior to detection, and many continue to drink drive following conviction. Few first offenders are offered treatment programs, and as such there is a need to address drink driving behaviour at this stage. A comprehensive approach including first offender treatment is needed to address the problem.

Online interventions have demonstrated effectiveness in reducing risky behaviours such as harmful substance use. Such interventions allow for personalised tailored content to be delivered to individuals targeting specific mechanisms of behavioural change. This method also allows for targeting screening to ensure relevance of content on an individual level. However, there have been no research based online programs to date aimed at reducing repeat drink driving by first offenders.

The Steering Clear First Offender Drink Driving Program is a self-guided, research based online program aimed at reducing recidivism by first time drink driving offenders. It includes a specialised web app to track drinks and build plans to prevent future drink driving. This allows for elongation of learning and encouragement of sustained behavioural change using self-monitoring after initial program completion. An outline of the program is discussed and the qualitative experience of the program on a sample of first offenders recruited at the time of court appearance is described.

Introduction

In Australia, over the decade between 2001 and 2010 on average some 1600 people died annually as a result of traffic crashes (Department of Infrastructure, Transport, Regional Development, & Local Government, 2010) and around a third of fatal crashes have alcohol use as a contributing factor (National Road Safety Council, 2010). According to the National Road Safety Strategy 2011-2020 (Australian Transport Council, 2011), interventions for drink driving may provide a substantial benefit to road safety. This report noted, in relation to the period between 2001 and 2010, that:

> 'There was some strengthening of drink driving measures over the decade, including adoption of tougher sanctions and the introduction of alcohol interlock programs for repeat or high-range offenders. However, while drink driving behaviour has been contained to a small proportion of the driver (and rider) population, it continues to be a major cause of serious road trauma — and there is evidence that a substantial proportion of drink drivers have serious alcohol abuse problems. In recent years there has been increasing focus on interventions targeting this 'hard core' minority of offenders' (p. 13).

It notes that a key action should be to review international best practice and identify cost effective interventions for dealing with high risk and repeat traffic offenders. The Steering Clear First

Offender Drink Driving Program aims to reduce the risks of repeat offending, by providing a cost-effective brief and research based method of intervention at the time of first conviction.

In Queensland in 2010, a drink driving discussion paper was tabled by TMR, as despite road safety gains achieved as a result of enforcement activities such as RBT, strengthening drink driving legislation including penalties and sanctions, public education campaigns, advertising campaigns and offender education programs, drink driving remains a significant factor in serious crashes on Queensland roads. In 2011/12, more than 3.3 million breath tests were performed (Queensland Police Service, 2012). The Queensland Police Service aims to test licenced drivers once per year, so the number of breath tests performed increases each year to keep up with population growth. The number of drink driving offences remains above 25,000 per year in Queensland alone, with the majority being detected with a BAC equal to or under 0.149g/100ml, and 73.1% of these being first time offenders, (TMR, 2010).

The TMR discussion paper noted that brief educational intervention may be particularly relevant to first time drink driving offenders, given the effectiveness of these programs over no treatment (TMR, 2010). In terms of delivery method, it was suggested that an online program may be an effective way to utilise technology and provide a widespread program to those who live in rural or remote areas or have employment or family commitments that prohibit them from being able to attend a face-to-face program (TMR, 2010). Based on the responses obtained to the questions outlined in this discussion paper, it was found that 74.9% of community respondents supported the initiative of mandatory brief educational interventions for first time offenders with a BAC less than 0.149g/100ml (Soole, King, & Watson, 2010).

While these discussions continue, there are no current programs targeted specifically at first offenders available in Queensland. The purpose of building the Steering Clear First Offender Drink Driving Program was to provide an option that would fill the gap in first offender assessment and treatment. The program is initially being trialled as a pilot program in Queensland with the potential for it to be tailored to other jurisdictions.

Online interventions for drink driving prevention.

Online interventions have had promising outcomes in the reduction of risky behaviours, including problematic alcohol use (White et al., 2010; Riper et al., 2011). In the context of drink driving, a brief online intervention for first time offenders could have the following benefits:

- Cost effectiveness
- Access
- Privacy and anonymity
- Autonomy, self-paced learning
- Compliance due to flexibility
- Social acceptability
- Interactive tailored learning

There also could be limitations of online drink driving programs, for example:

- The program may not be undertaken by the offender
- For some of the highest risk offenders such as high range and repeat drink drivers, more intensive face-to-face programs may be more suitable
- Confronting a therapist/facilitator may increase the specific deterrence effect

There are likely to be other benefits and limitations of online interventions designed to reduce drink driving and further research needs to be conducted to address any identified barriers, as well as to determine whether online programs demonstrate effectiveness in reducing risky illegal behaviour.

Program content

The program content is based on previous research into the behaviour of first offender drink drivers and the factors that lead to reoffending following a conviction (Wilson, 2015). The program has 5 core modules:

- Standard drinks
- Alcohol and the body
- Consequences of drink driving
- Planning ahead
- Your alcohol use

The program also includes an evaluation (questionnaire) module and an automated follow up email with a Certificate of Completion and personalised summary of the program attached. Program completion unlocks a self-monitoring web app that can be used at any time to track drinks and update plans to avoid drink driving.

Pilot methodology

The pilot evaluation has ethical approval by the University Human Research Ethics Committee (no. 1400000214). The pilot involves recruitment of first time drink driving offenders at the time of conviction in the Magistrates Court who are approached and asked if they would like to participate in the research project. Offenders are given a unique login code where they can access the program from their own home computer or mobile device. The program takes around 1.5-2 hours to complete, and pilot participants are offered a $50 voucher as reimbursement for taking part in the research project, sent to them on completion of all modules.

Preliminary pilot results

The pilot commenced in May 2015 in both Brisbane Magistrates Court and Cairns Magistrates Court with the support of the Chief Magistrate.

Early qualitative feedback on the program has been gathered from the offenders who have participated to date. The following are some descriptive responses from the evaluation module for the question ‘what have you learned from the program?’

‘Separate drinking from driving’
‘Measurement of alcohol content’
‘I think I spend a lot on alcohol per year‘
‘It’s risky to other road users if I drink and drive ‘
‘Ways to plan ahead before heading out and drinking’
‘If in doubt, don’t drive, regardless of what others might think’
‘I have to depend on other people if I can’t get public transport’
‘Making plans and right decisions about when drinking and how to know the right thing to be doing’

All of the offenders completing the pilot study to date have provided positive feedback about the program and the statements above indicate that they have considered factors relating to avoiding drink driving and their alcohol use as a result of taking part. The pilot recruitment continues. Future research will be conducted on a larger scale to determine the effects of the program in a longitudinal manner with outcomes such as retention and recall of key learning measures and its potential impact on drink driving behavioural change.

Conclusion

The Steering Clear First Offender Drink Driving Program is a novel online intervention program aimed at reducing reoffending by first offender drink drivers. Early pilot data suggests that the program is usable and offenders are finding the program to be a positive learning experience. Further research has been planned for the future of the program including a large scale longitudinal trial.

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Reducing the response times of emergency vehicles in Queensland

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Abstract

To address a growing and ageing population in Queensland and increased demand for emergency services, Transmax and the Queensland Government partnered to develop the successful Emergency Vehicle Priority (EVP) solution. EVP is a dynamic ITS solution that automatically interrupts normal traffic signal operations, providing a green traffic signal to emergency vehicles in advance of their arrival at an intersection. The benefit of this technology is that it helps reduce emergency vehicle travel times whilst enhancing the safety of front-line officers, other road users and the broader community.

The technology was trialled on the Gold Coast in Queensland in November 2012. The 20 EVP-enabled emergency response vehicles received more than 650 green traffic signals per week supporting in excess of 120 EVP-assisted incidents a week. Analysis indicated improvements in travel time of up to 20% along major routes with no measurable impact on congestion. A roll-out of the technology to other areas of Queensland commenced in 2014 and trial results have shown similar levels of travel-time improvements. There are 150 planned new EVP-enabled intersections at Bundaberg, Townsville, north-west Brisbane, the Gold Coast and Logan. In the first week of September 2014, EVP-enabled ambulance and fire vehicles received more than 2,500 green traffic lights during more than 600 Priority 1 events.

At the 2014 ITS Australia National ITS Awards, Transmax – along with Queensland Government Partners – won a national award in the Government category for Emergency Vehicle Priority (EVP) on Samford Road in Brisbane.

Introduction

Survivability in life-threatening situations is directly linked to the response time of emergency services. Despite legislation allowing emergency vehicles to progress through red traffic signals, safety procedures and waiting queues of vehicles necessarily slow the progression of these vehicles through the intersections as they must ensure cross-traffic has stopped to allow them to safely proceed. In the specific case of cardiac arrest, traffic delays of as little as three minutes can halve the chances of a patient’s survivability (see Figure 1). EVP safely delivers green traffic signals to emergency vehicles to allow their unimpeded passage through controlled intersections.

While there are other systems that provide green traffic signals to emergency response vehicles in defined circumstances, STREAMS EVP is the first known system in Australia to provide an intelligent, network-based system that automatically manages traffic before and after the emergency response vehicle passes.

In addition to addressing the need of emergency response vehicles to quickly and safely move through the network, EVP is designed to minimise disruptions to traffic and to seek a return to normal traffic conditions quickly after the emergency response vehicle has passed.

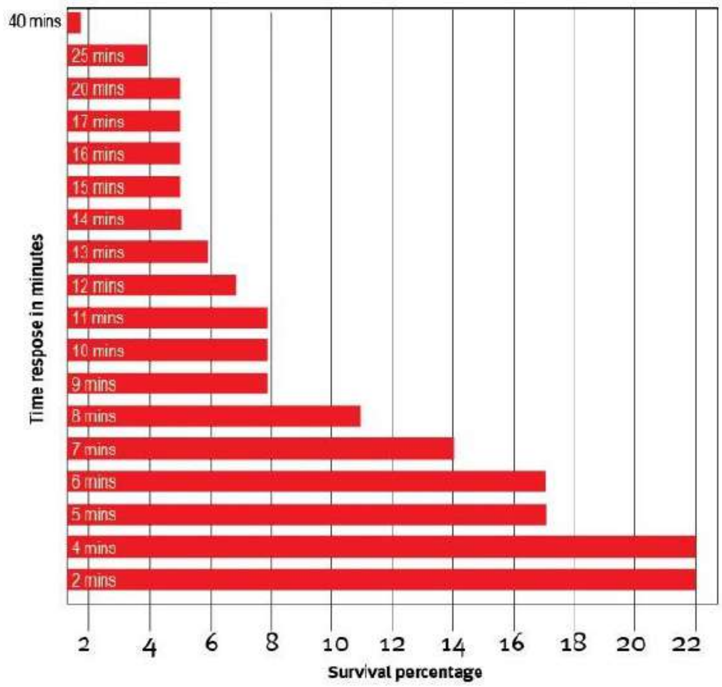

Figure 1. Survivability of cardiac arrest [1]

Initial Trial

In 2008, the Bundaberg fire, ambulance and police services participated in a proof-of-concept trial to explore the benefits of EVP. Eleven traffic signal installations (later extended to 18) were configured to enable EVP capability. This trial was conducted to test the capacity of signalised intersections to provide priority for four emergency response vehicles fitted with dedicated, on-board, automatic vehicle locator devices. Manual activation of the EVP system was required by the front-line officers who had to inform the system of the route on which they were travelling. The system then automatically tracked their progress along the selected route and intervened at downstream traffic signals as the emergency response vehicle passed fixed waypoints ahead of each intersection. Any deviation from the pre-selected route terminated the EVP assistance. An independent analysis of the proof-of-concept identified a reduction in travel times for the participating emergency response vehicles.

Pilot Project

Following the Bundaberg trial, the Queensland State Government approved a pilot project for Transmax to design, develop and enhance EVP capabilities. The pilot had the following principal objectives:

- Flexible development to support scalability and expansion to other potential users
- No change to business processes for front-line emergency staff (i.e. no manual selection or initiation of routes)
- Minimal change for road operations staff
- Use of existing systems and equipment where possible.

While the initial proof-of-concept limited the scope of change to the ITS itself, the pilot project was to utilise an expanded scope of integration across the emergency vehicle's existing location devices and computer-aided dispatch (CAD) systems as well as the necessary components within the ITS.

Southport (Figure 2) was selected as the preferred location due to:

- The Gold Coast Hospital servicing a large number of life-threatening conditions and injuries and therefore, potentially benefitting significantly from an EVP system
- Local ambulance stations being amongst the busiest in the state
- Increasing demands for emergency services in the area
- High local traffic volumes allowing for significant improvements through an intelligent EVP system.

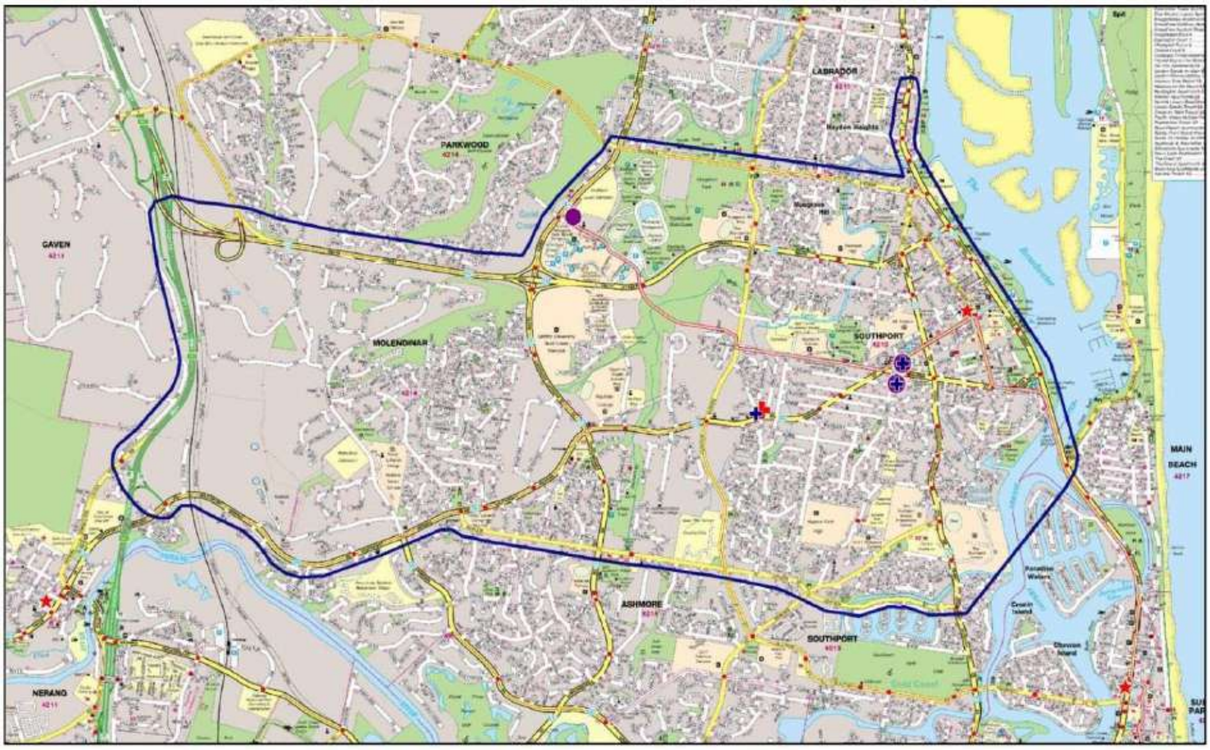

Figure 2. Southport Pilot Area

EVP Pilot System Design

Overview

The developed EVP system is an intelligent transport solution that provides target emergency response vehicles with priority access through the controlled road network. It is designed to use existing infrastructure to minimise installation and maintenance costs (not requiring additional hardware to be installed at intersections) and utilising in-vehicle equipment (mobile computers and GPS) often installed in emergency response vehicles. The system is broadly split into two separate subsystems that communicate through a well-defined formal interface:

- The Vehicle Tracking and Intervention Request (VTIR) subsystem (delivered by the Department of Community Services [DCS]) was designed and built across a number of components including: in-vehicle software; vehicle communication; state management;

route and ETA processing; and traffic signal communication. The VTIR tracks emergency vehicles in real time, calculates the estimated time of arrival at intersections, and sends requests to the STREAMS (Transmax ITS) traffic control system.

- The Traffic Signal Intervention (TSI) subsystem was designed and built into the existing ITS. It arbitrates requests received from the VTIR system against other traffic management requests and, where appropriate, manages traffic signals to service requests.

This relationship is depicted in Figure 3.

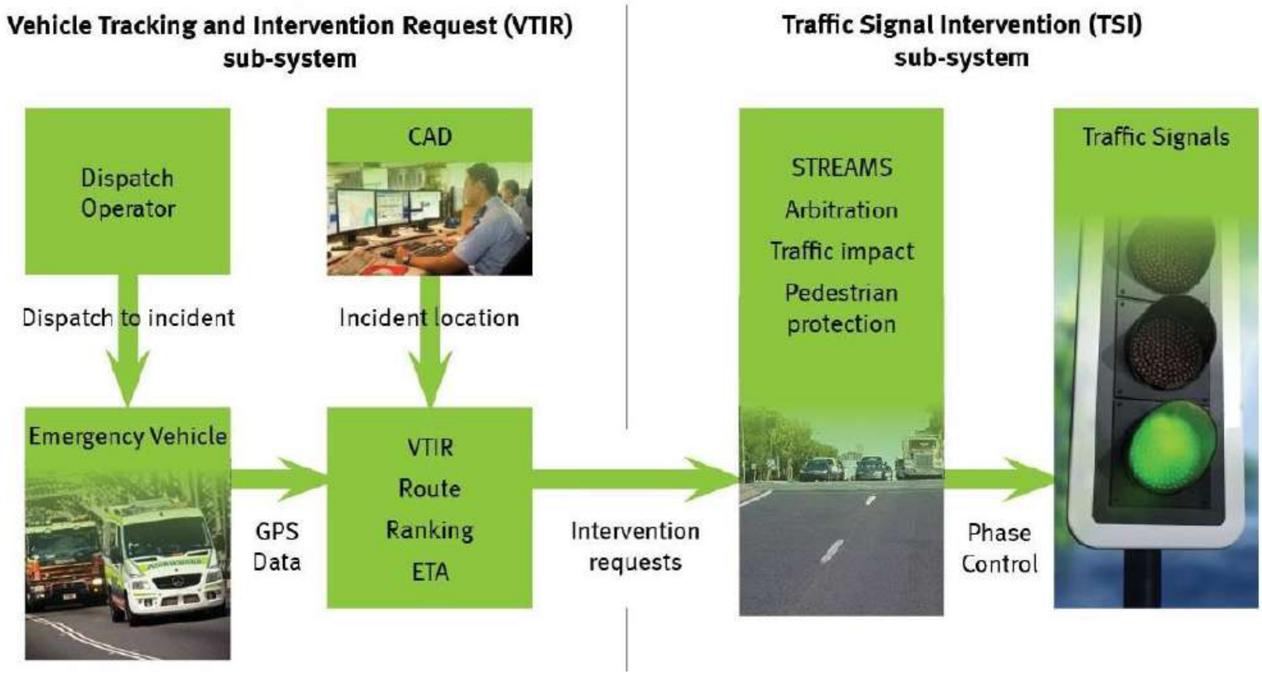

Figure 3. EVP Operational Overview

VTIR

The VTIR monitored the current location of emergency response vehicles, predicted their potential route, and sent intervention requests and ETAs to the traffic signal system to action. It achieved this by combining real-time information from the emergency response vehicles and the associated CAD system and spatial data relating to the road and signal networks to calculate the ETAs for likely intersection approaches.

The subsystem consisted of two components:

- In-vehicle equipment (IVE)
- VTIR subsystem

The IVE was a ruggedized Windows 7 box which was wired in to ambulance and fire vehicles in the pilot area. When an emergency vehicle's lights and sirens were activated, the IVE would send the vehicle's GPS location and bearing information every two seconds over the 3G network to the VTIR system. There was no user-accessible interface for the IVE so no intervention was required from field-officers to activate it.

The VTIR system accepted the messages from the IVE, married this information with Triple Zero Priority 1 emergency call information from ESCAD (the DCS emergency dispatch system) and calculated a potential route to the destination. It then requested intersections along that route that were controlled by the STREAMS system via the Traffic Signal Intervention (TSI) subsystem in TMR. These messages to TSI were also sent every two seconds. VTIR told TSI which intersection it was requesting and the ETA of the vehicle at the intersection. VTIR would then accept messages from TSI every two seconds reflecting the success or otherwise of intervention requests for the respective intersections.

There was no indication to the driver of the vehicle of the state of the EVP system and their vehicle's priority status with intersections on the route to the location. This was a policy decision to reduce the impact on the fire and ambulance front-line officer operational procedures.

Also, no route suggestion was made to the driver; VTIR would calculate the most likely route a driver would take to an event. Any deviations from this anticipated route resulted in the automatic cancellation of intervention requests to those intersections on the original anticipated route. A new anticipated route was automatically calculated based on the current direction of the vehicle resulting in corresponding intersection intervention requests being sent.

If a vehicle deviated from calculated routes more than a predefined number of times then VTIR would attempt to request interventions in the general direction of travel. If a vehicle took longer than anticipated to arrive at an intersection, the request for intervention on that intersection expired and the intersection resumed its normal operation. If two emergency vehicles requested priority at conflicting entrances to the same intersection and STREAMS had not already started the intersection, the highest priority request was served first.

TSI

The TSI delivered the appropriate traffic signal phase to provide a green traffic signal to the emergency response vehicle by the requested ETA while maintaining all safety critical factors. It provided traffic management intelligence to introduce the intervention phase, clearing queued traffic ahead of the emergency response vehicle as well as returning traffic to normal following the passage of the emergency response vehicle.

The TSI subsystem provided for arbitration based on a ranked priority per intersection. The highest priority requests asserted control over the intersection and held out other requests until it was either cancelled or exceeded the maximum permitted request time. This allowed for an orderly progression of vehicles based on priorities defined by the emergency services dispatch.

Once the prioritisation of interventions was resolved, the required interventions were scheduled on the controlled intersections to achieve the shortest possible departure from standard cycling, within safety constraints. These key restraints are shown in Figure 4.

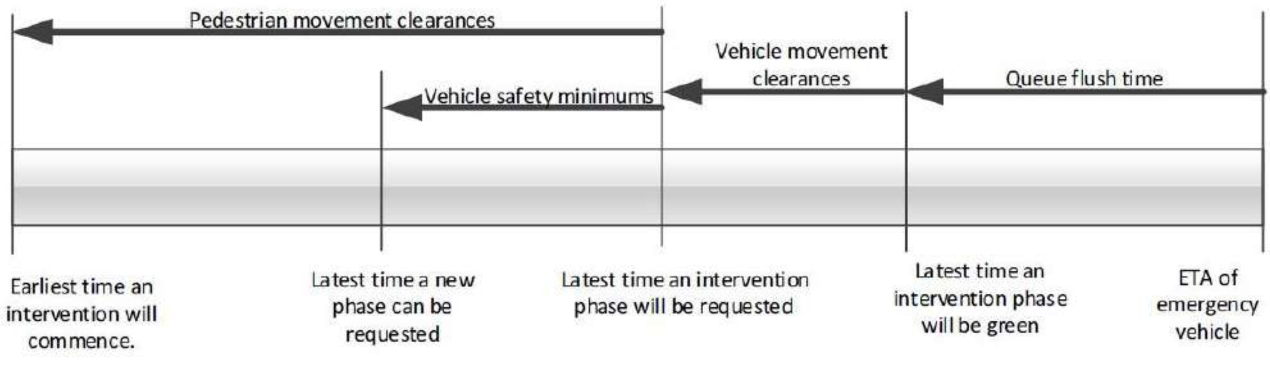

Figure 4. Intervention Timing Constraints

Following the transition of a vehicle through the intersection, clean-up strategies were implemented by the ITS to ensure an orderly and rapid progression back to normal operations.

Results

Overview

Analysis of logged trip data indicated that all 20 EVP-enabled emergency response vehicles benefitted from EVP receiving more than 650 green traffic signals per week supporting more than 120 incidents per week. Analysis also showed improvements in travel time of between 10%-20% along major routes and improvements in response times compared with the same period in the previous year.

Data Collection

Three commonly used routes for emergency response vehicles were identified in the Gold Coast area:

1. Westward on Southport-Nerang Road
2. Southward on Ferry Road
3. Northward on Kumbari Avenue.

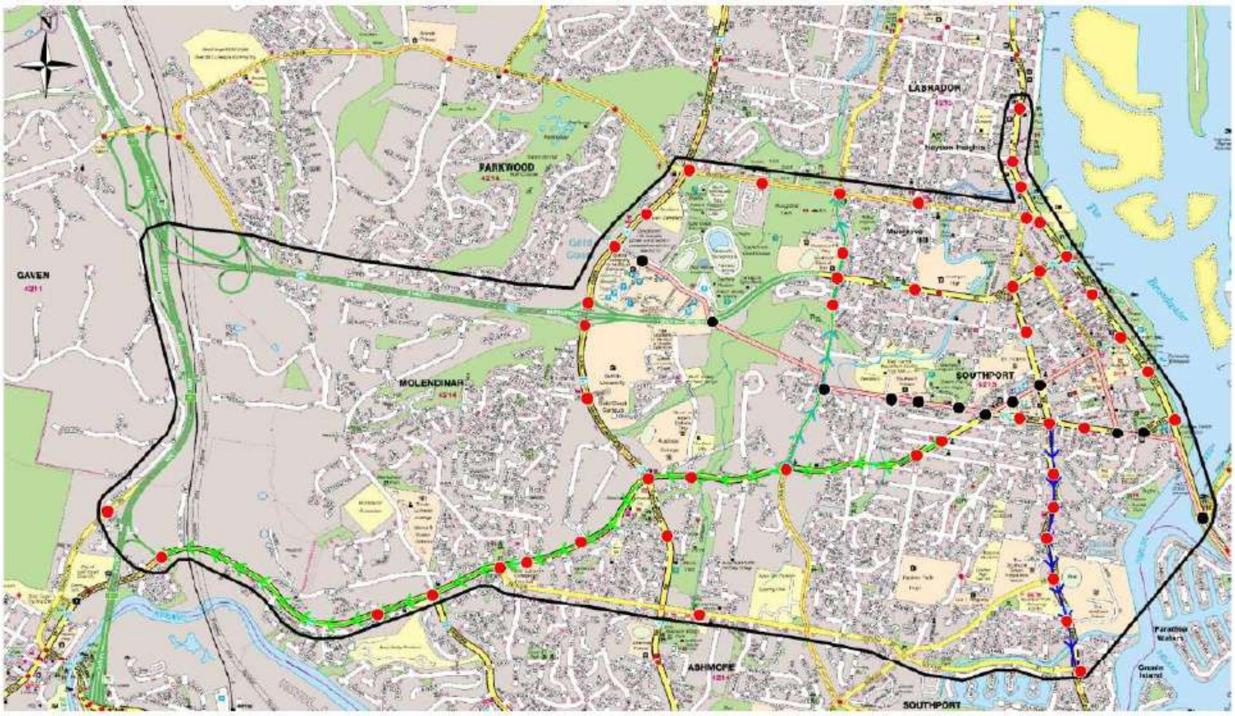

Figure 5. Measured Routes

GPS information from emergency vehicles was collated before and after system implementation to determine the impact of the system. Results are shown in Table 1.

Table 1. Average Trip Improvement

Route	Average Trip

	Improvement
Southport-Nerang Road	11%
Ferry Road	14.5%
Kumbari Avenue	20%

Analysis of general traffic data from before and after system implementation showed no significant differences in congestion.

User Feedback

Positive feedback has been received from paramedics and fire fighters who have been involved with EVP. The most common response when queried is that: "we noticed more green lights but just thought we were lucky". As noted by senior officers, this reflects the seamless integration of EVP into existing business practices and processes.

Further feedback from Queensland Ambulance Service staff has highlighted the issue that they got: "four or five green lights then went outside the pilot area and stopped in traffic".

The Traffic Management Centre (TMC) in Nerang on the Gold Coast manages the traffic and, in particular, STREAMS, where EVP was implemented. The feedback from TMC operators was that the EVP application did not add work to their normal operations.

Expansion to Other Areas of Queensland

Following the successful Southport pilot, trials of the technology in other areas of Queensland have commenced. In Bundaberg (population 71,000), the location of the original trial of first-generation EVP, traffic lights at 32 intersections in the city have been upgraded with seven fire engines and 14 ambulances from Bundaberg and surrounds having EVP technology enabled. In addition, in Queensland, there are 150 planned new EVP-enabled intersections at Bundaberg, Townsville, north-west Brisbane, the Gold Coast, and Logan.

In the first week of September 2014, EVP-enabled ambulance and fire vehicles received more than 2,500 traffic lights during more than 600 Priority 1 incidents.

The Brisbane EVP pilot undertaken on Samford Road in 2014/2015 demonstrated that the system can be used successfully with the SCATS®* adaptive traffic control software system and Transmax is now preparing to configure an additional 300 intersections in the traffic network controlled by Brisbane City Council.

The successful Brisbane pilot also demonstrates that Queensland's EVP technology could be expanded to many other cities as SCATS® is used for traffic signal control in more than 150 cities around the world.

While the EVP solution has been implemented for use by emergency response vehicles, there are many other potential users of this technology such as police VIP escorts, defence vehicle convoys, freight companies with wide loads, and other groups of road users where it would provide community benefit.

Summary

EVP is ultimately about saving lives and helping frontline officers respond as quickly as possible to incidents by getting there without risking the safety of other road users or disrupting traffic.

An increased demand for emergency services is driven by an ageing and growing population in Queensland. Coupled with traffic congestion, this means that smart technologies need to be employed to maintain and improve response times, keep other road users safe, and minimise traffic disruptions.

EVP leverages existing technology to deliver an intelligent transport solution without adding

*SCATS® is the registered trademark of Roads and Maritime Services (a NSW Government agency). The use of the SCATS® trademark does not indicate any endorsement by or connection with Roads and Maritime Services.

complexity to the work processes of front-line officers. The result is faster travel times and a safer work environment for front-line officers (including less stress due to them having to navigate fewer red lights) and with no detrimental impact on network operations or other drivers.

Investment in EVP technology is realising improved front-line communications capability within and between the State Government and regional councils. It is also realising benefits through leveraging existing assets and resources by integrating critical traffic management systems with core front-line information systems to maximise return on the Government's investment in information communications technologies.

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Are young adults' choice of travel mode changing?

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Abstract

Changes in travel mode choices among young adults have been observed in Europe and North America with marked declines in the percentages of those with drivers' licences. Declines in licensing rates have the potential to affect future transportation needs, preferences for non-driving transport modes, vehicle purchases, road safety and the environment. This study aimed to identify any changes in population-based driver and motorcycling licensing rates among young adults in Victoria, Australia. Licensing data for all Victorian adults from 2001-2014 was tabulated with ABS population data to examine age-related trends in licensing rates. The results indicated that driver licensing rates among Victorians aged 18-30 years have declined since 2001. In 2014, over 40% of 18-21 year old Victorians did not have a driver's licence. This licensing decline was accompanied by substantial increases in the proportions of licensed drivers aged over 50 years, indicating that the decline is specific to young adults. The licensing data also revealed that motorcycling licensing rates have increased during recent years across most age groups in Victoria. However young adults aged 18-25 years have the highest rates of motorcycle only licences, with motorcycling only licensing rates increasing most notably among 22-25 year olds. Potential implications of such changes in travel modes include reduced road infrastructure revenue and costs, reduced traffic congestion, environmental benefits and reduced road deaths and injuries, but also a need for safer infrastructure for motorcycling and other travel modes.

Introduction

Changes in travel mode choices among young adults have been reported in several countries including the United States, Canada, Sweden, Norway, the United Kingdom and Germany (Sivak & Schoettle, 2012; van Dender & Clever, 2013), but also Australia (NSW) (Raimond & Milthorpe, 2010) with marked declines in the proportion holding a driver's licence. These declines are unique to young adults as they occur alongside increased proportions of licensed drivers of other ages. Common reasons given by young adults for not holding a driver's licence include that they are too busy to get a licence; owning and maintaining a vehicle is too expensive; they are able to get transport from others; and that they prefer walking, cycling or public transport to driving as travel mode choices (Davis et al., 2012; Dutzik et al., 2014; Foss et al., 2014; Le Vine & Polak, 2014; Sivak & Schoettle, 2013).

There are likely to be many inter-linked, societal-level factors influencing whether or not and, if so, when to obtain a licence, as well as choice of alternative travel modes. These factors include:

- transport planning policies, economic circumstances and market forces restricting access to and usage of cars (Metz, 2013; Sivak, 2014; van Dender & Clever, 2013);
- a delayed transition from teenage to adult lifestyles (Aretun & Nordbakke, 2014; van der Waard, et al., 2014);
- increased use of bicycle and car-sharing schemes (Strang & Mead, 2013; van der Waard, et al., 2014);
- a devaluing of car ownership and car use as a lifestyle characteristic (Delbosc & Currie, 2013; Kronenberg, 2010).

Also, public transport is becoming an increasingly more attractive choice among the young (at least for those who have good access to it) due to convenience, shorter travel times and that it facilitates sustained use of technological equipment such as smartphones and laptops (Davis et al., 2012; TransitCenter, 2014). Many jurisdictions explicitly ban young drivers from using hand held mobile phone technologies, thus providing a further incentive to travel as a passenger. In addition, many young people prefer to work from home or other convenient locations rather than physically travel to business premises (Pirdavani et al., 2014).

The present study explored evidence of driver licensing decline among young people in Victoria, Australia. Declines in licensing rates have the potential to affect future transportation needs, preferences for non-driving travel modes, vehicle purchases, and could have road safety and environmental consequences. As motorcycling has enjoyed increased popularity in Australia during recent years (e.g. Weissenfeld et al., 2011), motorcycle licensing rates were also examined to determine whether young adults might be using them as an alternative mode of transport. This study focussed on the potential road safety implications of changing travel mode choices of young adults because much of the existing research has been conducted from sociological and public transport planning perspectives, with very little attention paid to potential road safety implications.

Method

The total number of licensed drivers (probationary and full combined) at each age from 18 to 90 years for the years 2001 to 2014 were obtained from VicRoads. The driver licence numbers by age were tabulated alongside respective ABS population data for Victoria, and the percentage of licensed drivers then calculated for each age category across 2001-2014.

Motorcycle licensing data was also obtained from VicRoads. Data was examined for the years 2011 to 2014 concerning the numbers of motorcycle (BIKE class) only licences held, as well as numbers of motorcycle endorsements to car licences. The time frame was limited due to data availability but allows for examination of recent trends, particularly since the introduction of the Victorian motorcycle GLS in 2010. As with the driver licensing data, the percentage of licensed motorcycle riders by age group was calculated based on ABS population data.

Results

Driver licensing rates in Victoria

Figure 1 shows the licensing rates of Victorian drivers over time by age group. Between 2001 and 2014, there was an overall decline in the proportion of Victorians aged 18-21 years who were licensed with only 59% of 18-21 year olds holding a driver's licence in 2014. The most marked decline was seen for 18 year olds, with 53% holding a driver's licence in 2001, dropping to 40% by 2014. Licensing rates among those aged 22-25 years also decreased, from 89% in 2001 to 75% in 2014 and for those aged 26-30 years (95%: 2001 - 85%: 2014). For further details concerning licensing rates by age see the full report: Bailey et al, 2015. It is possible that the decrease in licensing for those aged 18-21 years in 2010 was partly attributable to the introduction of a number of changes to the Victorian Graduated Licensing Scheme (GLS) in 2007 and 2008 (see discussion).

By contrast, the licensing rate for ages 31-50 years showed an overall pattern of little change. However, the age group 51-90 years experienced a steady increase in licensing across 2001-2014, with the steepest rates found among those aged over 60. Importantly, these trends for drivers aged 30-90 years are inconsistent with the declining patterns found for drivers aged under 30, demonstrating that the declining licensing rates of young drivers constitute a unique phenomenon not part of a broader licensing pattern.

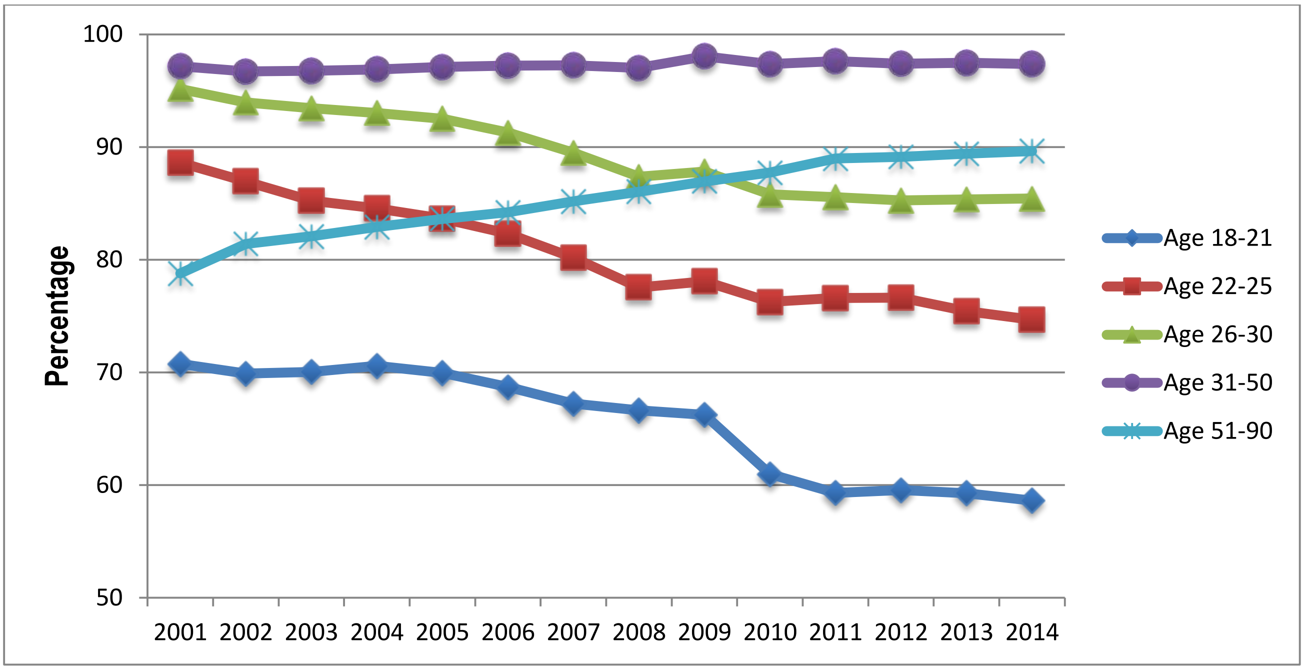

Figure 1. Licensing rates as percentages of Victorian population, by age, 2001-2014

Motorcycle licensing rates in Victoria

In Victoria from 2011 to 2014, there was an overall increase in motorcycle licensing from 8.7% to 9.1% of the population for riders aged 18-70 years. Figure 2 presents the licensing rate by population for Victorian motorcycle riders from 2011 to 2014 by age group. These rates include motorcycle only licences and motorcycle endorsements on class car licences. All age groups, with the exception of riders aged 31-50 years, experienced an increase in motorcycle licencing rates across the period. Riders aged 51 years and over had the greatest increase (19%) in rates, followed by riders aged 22-25 years (13% increase). People aged 31-50 years recorded the highest rates of motorcycle licensing.

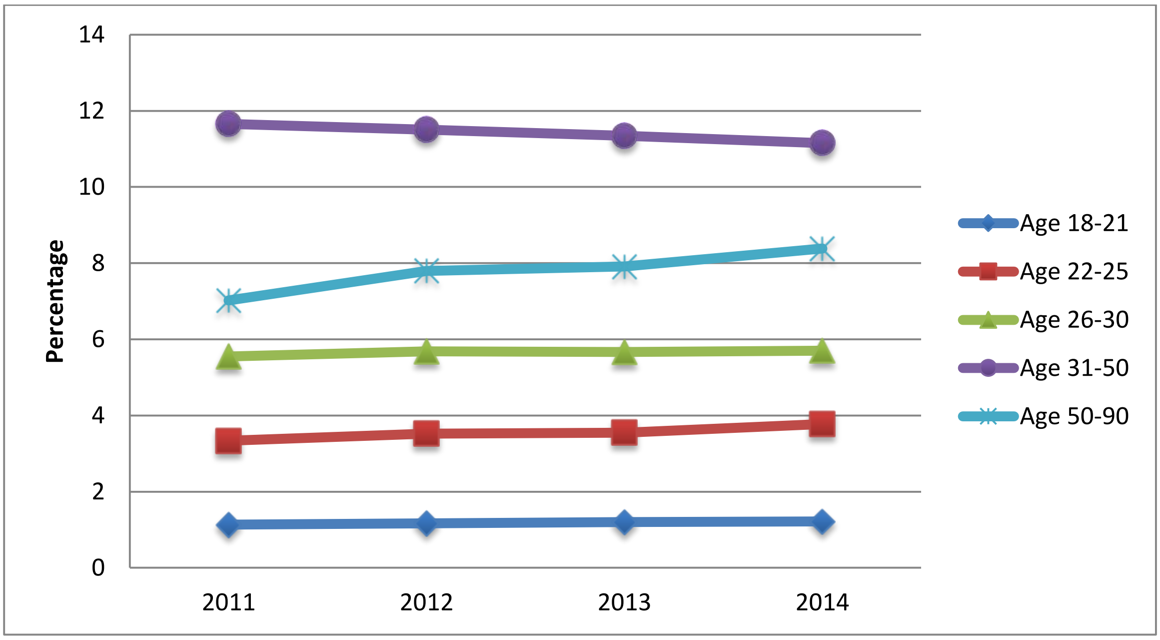

Figure 2. Motorcycle licensing rates as percentages of Victorian population, by age, 2011-2014

The rates per population for Victorians holding motorcycle *only* licences, as seen in Figure 3, indicate that young adults aged 18-25 years have the highest licensing rates of all age groups. Importantly, there was a 40% increase in motorcycle only licensing from 2011 to 2014 for 22-25 year olds. There were few notable changes for other age groups. Note that generally there were very low rates of motorcycle licensing in each age group so these results should be interpreted with caution.

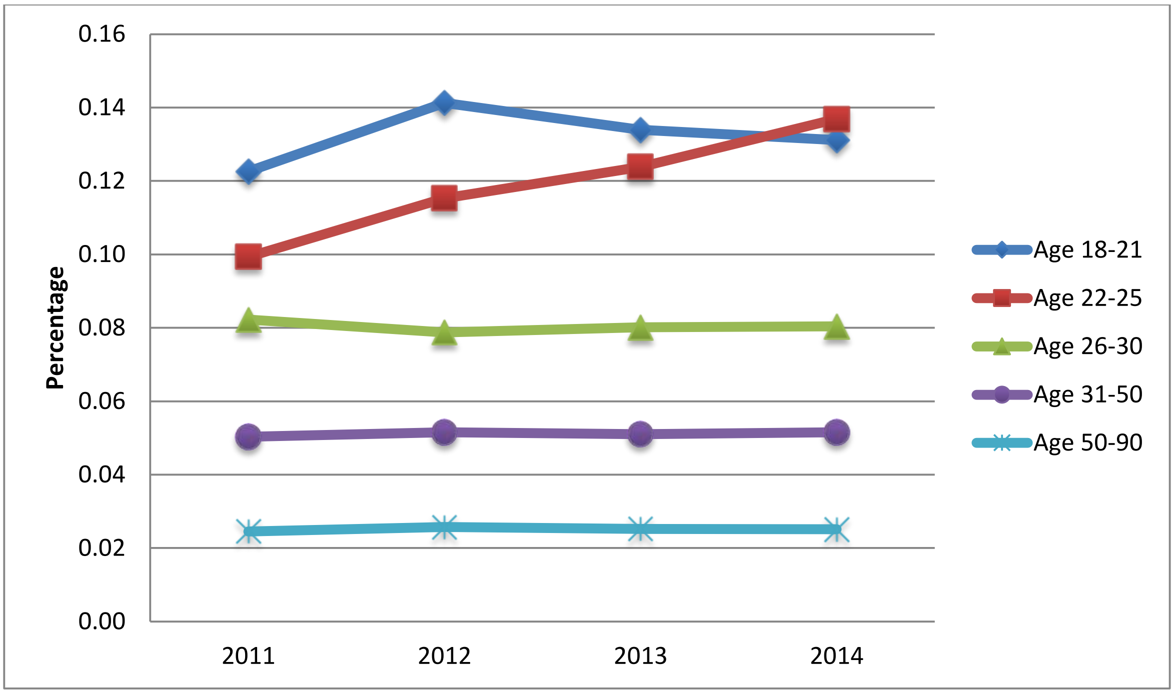

Figure 3. Motorcycle only licensing rates as percentages of Victorian population, by age, 2011-2014

Discussion: Implications for Road Safety

Consistent with previous research (e.g. Raimond & Milthorpe, 2010; Sivak & Schoettle, 2012), the findings from this study point to a continuing pattern of driver licensing decline among young adults in Victoria. A small increase in motorcycle licensing was also found. In particular, it appears that young adults aged 22-25 are increasingly obtaining a motorcycle licence only and not a car licence. It is possible that the higher level of motorcycle licensing only among this age group is partially attributable to riders waiting until they are over 21 years so that they might avoid the probationary licensing requirement to complete 12 months under P1 conditions (applicable to <21 years, no car licence). However, this possibility does not necessarily explain the increase from 2011 to 2014 as these conditions were present before 2011. Further analyses of motorcycling data over time is needed to establish any trends.

One specific external factor may have contributed to the more marked declines in licensing found among the youngest drivers. On 1 July 2007, Victoria introduced a new GLS requiring a minimum 12 months on a learner's permit (previously 6 months) and a minimum 120 hours of supervised driving experience for those aged under 21 at the time of licensing. The change also included a ban on mobile phone use while driving and restrictions on high-powered vehicles for probationary licence drivers. In the following year, the probationary period was extended from 3 to 4 years, with other restrictions imposed such as a maximum number of peer-age passengers and a requirement for a good driving record before graduation from a P1 to a P2 licence and from P2 to a full licence (Healy, Catchpole & Harrison, 2012). In addition a new drive test was introduced on 1 July 2008 which resulted in a lower pass rate than the previous test (Healy, Catchpole & Harrison, 2012). Consequently, the numbers gaining licences would have dropped in the short term and may have deterred some drivers from getting a probationary licence. It seems likely that the requirement for 12 months on a learner's permit would have directly reduced the numbers of learner drivers gaining licences from 2007 for the following year or two, but this alone does not explain the continuing pattern of licence decline among young adults.

It is not certain to what extent these findings might be indicative of trends over the coming decades. In particular, it is not known if the present generation of young adults who do not drive will tend to maintain this choice as they get older, or if they will adopt transport mode choices more traditionally associated with middle adulthood and raising a family (Dutzik et al., 2014; Sigurðardóttir et al., 2014), which are often more car-reliant. Added to this is evidence of a declining need to travel from the rising popularity of working from home among the young (Pirdavani, et al., 2014).

Assuming that such licensing and population trends persist into the future, several implications for road safety can be suggested, fortunately mainly positive ones. A trend for fewer young adults being licensed, along with preferences for other travel modes such as increased use of public transport in Australia (Richardson & Elaurant, 2013), will mean reduced overall young driver exposure to the road, which potentially could bring fewer crashes involving young drivers and their passengers (Dutzik et al., 2014). However, these benefits may be limited by the extent to which these young people become vulnerable road users in other transport modes, such as motorcycling. Consequently, there will be an ongoing need for infrastructure measures that support safe motorcycling, cycling, and walking (Richardson & Elaurant, 2013).

Conclusion

Patterns of licensing decline among Victorian 18-30 year olds have existed since at least 2001, which means the declines were evident well before the more stringent GLS introduced around 2007-8. By 2014, over 40% of 18-21 year old Victorians were not licensed to drive, although some of these may have been delaying a decision to obtain a licence. By contrast, motorcycling licensing rates have increased slightly during recent years across most age groups in Victoria. Young adults aged 18-25 years have the highest rates of motorcycle only licences, with motorcycling only licensing rates increasing most substantially among 22-25 year olds although numbers are still low. While this was an exploratory study of licensing data, further research could employ statistical modelling and investigate whether these trends continue over time.

Acknowledgements

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Empirical Analysis of Speeding Behaviour and Determining Speed Limits for Bicycles

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Abstract

Background

Electric bicycle (EB) has been increasing rapidly in China, and reached approximately 200 million in 2013 (Xinhua News, 2013). On the one hand, China has the strictest law for EBs with the lowest speed limit compared to the other countries. On the other hand, EB-related deaths and injuries have been very severe and up to 5,314 and 26,966 in 2012 (Ministry of Public Security in China, 2012). There has been little research on speed limit for bicycles, and resulting in the development of relevant laws and policies for speed limit of EB is difficult and no evidence-based.

Objectives

To describe potentially speeding riding behaviors for different types of bicycles, to investigate factors influencing the speeding practices in China, and to propose a model for determining the speed limits for EBs under different conditions.

Methods

Field bicycle data were collected from eleven sections of bicycle lanes in the urban district of Hangzhou, Zhejiang Province, China. The camera was carefully and covertly set up on the roadside of the separated bicycle lanes to record the operational behavior of both EB and regular bicycle (RB). The speed, bicycle type (RB, bicycle-style-electric-bicycle (BSEB), or shooter-style-electric-bicycle (SSEB)), gender (male or female), age (young, middle-aged, or elderly), and whether or not carrying something for each bicycle were collected and coded as binary (Jin et al., 2015). Mixed logistic regression models were applied to calculate adjusted odds ratio

(OR) and associated 95% confidence interval (CI) for the association between speeding and its influencing factors. Stepwise multiple regression models were then proposed for modeling the relationships between the 85th percentile speeds for different types of bicycles and their influencing factors. The speed limits under different widths of bicycle lanes can be calculated and determined using the 85th percentile speed models under free flow condition (Fitzpatrick et al., 2003).

Results

With an increase in widths of bicycle lane, the percentages of speeding bicycles increase quickly. For the speed limit of 20 km/h, the total percentages of speeding at site 1-4 (widths of lanes less than 3 m) are around 10%, whereas more than 30% for wider bicycle lane (greater than 3.5 m). Only 5.7% RBs exceed the designed speed limit of 20 km/h, however, there were still more than 30% EBs exceeding the speed limit. The results in Table 1 show that the original speed limit standards (15 or 20 km/h) are inconsistent with the actual situation, the speeding behaviors of bicycles are widespread in China. Therefore, the observed high prevalence of speeding for EBs (both BSEBs and SSEBs) implies a need for the improvement and change of speed limit policy.

For all sites, speeding was found to be associated with low bicycle volume. Meanwhile, six sites have been found that medium bicycle volume significantly elevated ORs (range from 1.60 to 3.61), and five sites no significant effect. BSEBs and SSEBs were associated with speeding. The maximum speeding risk (OR) for BSEBs and SSEBs are 12.97 (95% CI 8.30 to 12.59) at site 1 and 20.28 (95% CI 13.32 to 30.86) at site 2, respectively. Male cyclists were associated with of marginally elevated ORs (range from 1.51 to 2.12) at all sites. For the majority of sites, no statistically significant evidence have indicated that the existence of age and carrying factors were associated with elevated and reduced ORs of speeding, respectively. Detailed results are shown in Table 2.

The multiple regression results show that the width of bicycle lane and volume are two significant variables for all types of bicycles to estimate the 85th percentile speeds, whereas the gender-, age-, and carrying-related influencing factors have no significant effect on the 85th percentile speeds. The percentages of BSEBs and SSEBs have significant effect on the 85th percentile speeds for EB-related bicycle traffic flow. Figure 1 shows the estimated speed limits for different widths of bicycle lanes.

Table 1 Percentages of speeding bicycles under different speed limit.

Site	Speed limit 15 km/h				Speed limit 20 km/h				Speed limit 25 km/h			
	RB	BSEB	SSEB	Total	RB	BSEB	SSEB	Total	RB	BSEB	SSEB	Total
1	18.3%	41.1%	42.1%	34.4%	1.8%	14.1%	14.5%	10.5%	0.1%	1.1%	2.3%	1.4%
2	14.3%	34.4%	36.4%	28.9%	0.6%	7.8%	12.0%	7.6%	0.0%	1.6%	1.9%	1.3%

3	15.2%	41.7%	48.4%	33.9%	1.2%	10.0%	17.1%	9.6%	0.0%	1.3%	1.8%	1.0%
4	22.5%	44.3%	47.2%	39.4%	2.8%	15.7%	20.1%	14.3%	0.2%	0.7%	3.9%	2.3%
5	30.6%	59.5%	55.4%	45.4%	5.8%	31.1%	31.3%	20.1%	0.8%	7.4%	11.2%	5.9%
6	54.6%	83.5%	85.0%	74.5%	8.8%	42.4%	52.1%	35.6%	0.7%	9.0%	15.6%	9.3%
7	64.5%	84.8%	89.4%	78.5%	12.2%	45.8%	58.5%	37.7%	0.8%	7.9%	16.7%	9.0%
8	25.5%	58.8%	62.7%	53.5%	3.8%	28.4%	33.8%	26.0%	0.5%	6.5%	10.4%	7.4%
9	47.1%	70.1%	78.0%	68.9%	6.0%	34.1%	42.4%	31.7%	0.2%	7.5%	12.8%	8.8%
10	48.9%	76.2%	78.9%	69.0%	6.4%	37.4%	47.9%	33.2%	0.5%	6.8%	17.1%	10.2%
11	50.2%	81.5%	83.8%	76.9%	8.8%	44.4%	50.1%	41.3%	1.3%	11.8%	16.1%	12.6%
Total	37.2%	64.4%	68.6%	58.5%	5.7%	30.8%	38.1%	27.2%	0.5%	6.5%	11.5%	7.4%

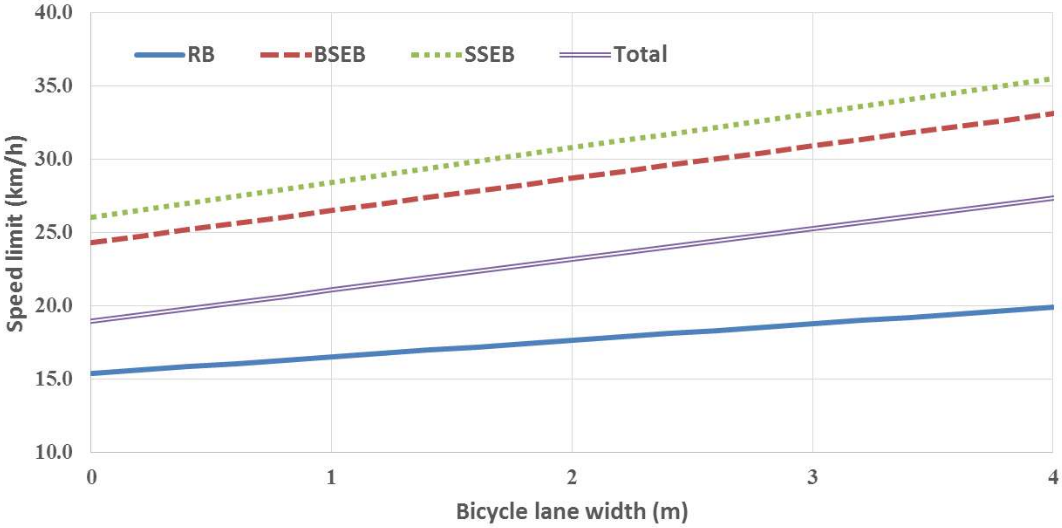

Fig. 1 Estimated speed limits for different widths of bicycle lanes.

Table 2 Logistic regression results for individual speeding.

Site		Bicycle volume			Bicycle type			Gender		Age			Carrying	
		Low	Medium	High	BSEB	SSEB	RB	Male	Female	Young	Middle-aged	Elderly	Passenger	Oversized cargo
	OR	***2.45***	***1.60***		***9.54***	***8.68***		***1.70***		1.64	1.56		0.76	0.67
1	95% CI	***(1.91 3.15)***	***(1.41 1.82)***		***(7.22 12.59)***	***(6.72 11.23)***		***(1.48 1.97)***		(1.12 2.40)	(1.04 2.35)		(0.61 0.95)	(0.49 0.91)
	p-value	***0.000***	***0.000***		***0.000***	***0.000***		***0.000***		0.199	0.271		0.209	0.197
	OR	***6.72***	***3.61***		***12.97***	***20.28***		***1.80***		1.91	1.61		***0.31***	0.64
2	95% CI	***(5.49 8.22)***	***(3.02 4.31)***		***(8.30 20.28)***	***(13.32 30.86)***		***(1.52 2.13)***		(1.12 3.27)	(0.93 2.78)		***(0.22 0.44)***	(0.44 0.94)
	p-value	***0.000***	***0.000***		***0.000***	***0.000***		***0.001***		0.229	0.385		***0.001***	0.248
	OR	***2.63***	***2.38***		***10.18***	***16.89***		***2.05***		1.39	1.00		0.62	0.90
3	95% CI	***(2.25 3.08)***	***(2.05 2.75)***		***(7.06 14.68)***	***(12.28 23.22)***		***(1.71 2.45)***		(1.11 1.75)	(0.79 1.27)		(0.44 0.87)	(0.66 1.24)
	p-value	***0.000***	***0.000***		***0.000***	***0.000***		***0.000***		0.145	0.994		0.156	0.746
	OR	***2.89***	***1.46***	Reference	***7.86***	***9.22***	Reference	***1.62***	Reference	0.89	0.95	Reference	***0.54***	***0.47***
4	95% CI	***(2.45 3.42)***	***(1.30 1.64)***		***(6.30 9.81)***	***(7.59 11.21)***		***(1.45 1.80)***		(0.73 1.08)	(0.78 1.17)		***(0.41 0.72)***	***(0.33 0.67)***
	p-value	***0.000***	***0.001***		***0.000***	***0.000***		***0.000***		0.558	0.806		***0.031***	***0.037***
	OR	***5.20***	0.98		***6.73***	***6.65***		***1.51***		***2.14***	1.68		0.81	1.14
5	95% CI	***(4.49 6.03)***	(0.85 1.13)		***(5.76 7.85)***	***(5.81 7.62)***		***(1.36 1.69)***		***(1.63 2.83)***	(1.26 2.25)		(0.68 0.95)	(0.91 1.43)
	p-value	***0.000***	0.898		***0.000***	***0.000***		***0.000***		***0.006***	0.074		0.202	0.563
	OR	***3.87***	0.89		***8.64***	***11.31***		***1.64***		1.37	1.38		0.81	0.65
6	95% CI	***(3.38 4.44)***	(0.83 0.94)		***(7.38 10.11)***	***(9.87 12.96)***		***(1.48 1.82)***		(1.13 1.66)	(1.13 1.68)		(0.70 0.94)	(0.50 0.84)
	p-value	***0.000***	0.91		***0.000***	***0.000***		***0.000***		0.103	0.104		0.160	0.096
7	OR	***3.24***	1.37		***8.67***	***11.07***		***2.12***		***2.51***	***2.05***		***0.19***	***0.41***

	95% CI	***(2.52 4.15)***	(1.07 1.76)	***(7.47 10.07)***	***(9.92 12.36)***	***(1.92 2.35)***	***(1.87 3.36)***	***(1.51 2.77)***	***(0.15 0.26)***	***(0.33 0.52)***
	p-value	***0.000***	0.198	***0.000***	***0.000***	***0.000***	***0.002***	***0.018***	***0.000***	***0.000***
	OR	***5.48***	1.57	***12.17***	***13.92***	***1.75***	1.50	1.36	***0.49***	0.69
8	95% CI	***(4.17 7.20)***	(1.22 2.03)	***(9.83 15.08)***	***(11.42 16.96)***	***(1.60 1.92)***	(1.18 1.91)	(1.06 1.74)	***(0.42 0.58)***	(0.52 0.91)
	p-value	***0.000***	0.077	***0.000***	***0.000***	***0.000***	0.087	0.212	***0.000***	0.176
	OR	***1.59***	1.57	***8.44***	***10.64***	***1.83***	***2.79***	***2.16***	1.22	0.84
9	95% CI	***(1.42 1.78)***	(1.22 2.03)	***(6.79 10.48)***	***(8.84 12.80)***	***(1.60 2.10)***	***(2.03 3.83)***	***(1.55 2.99)***	(0.90 1.66)	(0.71 0.99)
	p-value	***0.000***	0.125	***0.000***	***0.000***	***0.000***	***0.001***	***0.019***	0.508	0.296
	OR	***7.72***	***2.18***	***11.47***	***13.31***	***1.68***	***1.94***	***1.78***	0.67	***0.68***
10	95% CI	***(6.64 8.99)***	***(1.89 2.53)***	***(9.99 13.16)***	***(11.83 14.97)***	***(1.55 1.82)***	***(1.68 2.24)***	***(1.52 2.08)***	(0.55 0.83)	***(0.59 0.79)***
	p-value	***0.000***	***0.000***	***0.000***	***0.000***	***0.000***	***0.000***	***0.000***	0.059	***0.010***
	OR	***3.08***	***2.01***	***9.89***	***11.27***	***1.61***	***1.56***	1.14	***0.66***	***0.82***
11	95% CI	***(2.70 3.50)***	***(1.91 2.10)***	***(8.93 10.95)***	***(10.31 12.33)***	***(1.53 1.69)***	***(1.39 1.76)***	(1.01 1.29)	***(0.61 0.71)***	***(0.74 0.91)***
	p-value	***0.000***	***0.000***	***0.000***	***0.000***	***0.000***	***0.000***	0.265	***0.000***	***0.047***

Note: Significant results are highlighted in bold italics

Conclusions

For RBs, the original speed limit (15 or 20 km/h) in China is reasonable. For the bicycle lanes where have great majority of EBs, it is recommended that the speed limit of EBs is 25-30 km/h for the width of bicycle lane less than 3 m, and 30-35 km/h for that larger than 3 m. For the bicycle lanes with heterogeneous bicycles traffic, it is recommended to maintain the existing 20 km/h speed limit for the width of bicycle lane less than 3 m, meanwhile it is considered to increase the speed limit to 25 km/h for the width larger than 3 m. The study findings indicate that there should be a need to change the speed limit policy for EBs in China.

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Response to Review Comments on Manuscript (JACRS-D-15-00114)

Empirical Analysis of Speeding Behavior and Determining Speed Limits for Bicycles

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We wish to express our gratitude to Assisting Editor and the anonymous reviewer for their valuable suggestions and comments on this manuscript. Since receiving the comments, we have carefully addressed the issues raised and made the corresponding changes. The following is the detailed response to the comments from the reviewer.

Response to Comments of Reviewer 1

General Comment:

The paper summarises speeding and speed thresholds for bicycles. For such a short paper the authors should put a bit more effort into completeness;

Response:

We appreciate your comments. Because this manuscript is an extended abstract, the method and conclusions are simple. We have added some conclusions and references according to the reviewer's suggestion.

Comment 1-1: *the title says electric bicycle but the paper addresses all bicycles*

Response: According to the suggestion, we use "bicycle" replaced of "electric bicycle"

Comment 1-2: *the front abstract is entirely different to the paper abstract*

<u>Response:</u> The front abstract is the first version, we have revised the new abstract in the revision.

<u>Comment 1-3:</u> *there is not sufficient detail of results to understand your conclusions (you don't even have any counts) - either add a reference to the full results or provide more detail eg you discuss 85th percentile speed results with no data*

<u>Response:</u> We are sorry for unclear detail of results, due to the length of extended abstract. We have added some reference and conclusions in the revised manuscript.

<u>Comment 1-4:</u> *Table 1 and Fig 1 aren't referred to*

<u>Response:</u> Table 1 and Fig 1 are cited in the paper.

<u>Comment 1-5:</u> *there are no references*

<u>Response:</u> Some important references have added in the revision.

<u>Comment 1-6:</u> *please justify the conclusion that because you found large numbers of cyclists exceeding the speed limit the speed limit should therefore be raised*

<u>Response:</u> In this paper, we used 85^{th} percentile speed of bicycle as the speed limit. The results show that the estimated limit speed exceeds the existing speed limit. Therefore, it is recommended to increase the speed limit.