



Journal of the Australasian College of Road Safety

Formerly RoadWise – Australia's First Road Safety Journal



Special Issue - Safe Driving for Work

Peer-reviewed papers

- Work-related road safety in Australia, the United Kingdom and the United States of America: an overview of regulatory approaches and recommendations to enhance strategy and practice
- Effects of mobile phone distraction on drivers' reaction times
- Safety performance functions for traffic signals: phasing and geometry
- Use of Kloeden et al's relative risk curves and confidence limits to estimate crashes attributable to low and high level speeding

Contributed articles

- Smarter travel @ work: achieving road safety outcomes by reducing workplace travel
- Corporate road safety: an opportunity to reduce the road toll through integrated government policy
- Children locked in vehicles: implications for organisational and community safety

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The 2013 Australasian College of Road Safety Conference will be held in Adelaide at the National Wine Centre of Australia on **Thursday & Friday, 7–8 November 2013** with a welcome reception on the evening of Wednesday 6 November.

The Conference provides a valuable opportunity for participants to hear about the latest developments in road safety and have discussions with leading researchers, senior policy makers and experienced practitioners. Emphasis is placed on networking, information sharing and the translation of road safety research and policy into practice.

In addition to general papers on various road safety topics, this year's conference will contain a special stream on **what influences the public perception of road safety problems and the issues that need to be discussed** if we are to make significant progress in reducing road trauma over the next decade.

Who should attend

The primary aim of the ACRS Conference is to provide a rich environment to encourage best possible outcomes to save lives and reduce injuries on our roads

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This includes:

- o Journalists, editors and public relations
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- o Researchers and academics
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- o Policy makers
- o Law enforcers and legislators
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- o Engineers
- o Psychologists
- o Students in the road safety disciplines
- o Consultants
- o Private sector organisations
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- o Any others with an interest in road safety

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<http://acrs.org.au/conference>

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www.acrs.org.au/award

Entries open 1st May 2013 and close 5pm (EST), 13th September 2013.

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“Together we can improve road safety”

Become a member of the College today!

The Australasian College of Road Safety (ACRS) is the peak membership association focussed on saving lives and injuries on our roads.

What membership benefits do we provide?

- **Communication** – weekly e-newsletters, quarterly peer-reviewed journal, social platforms (LinkedIn and Facebook), media releases... **We keep you up to date!**
- **Professionalism** – Awards, Code of Professional Conduct.... **We reward innovations to save lives and injuries!**
- **Accreditation** – Register of Road Safety Professionals.... **We support our experts!**
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- **Advocacy** – International, AustralasiaOn, National and Chapter-based advocacy.... **We talk to those in leadership positions on your behalf!**

Who can be members?

In a word: Everyone!

Individuals contribute a variety of views and perspectives.

A range of **businesses** bring expertise and innovations which contribute to road safety.

Community organisations can use their membership to join with others to promote changes to improve road safety. Success stories are shared with other Councils and groups.

The College promotes **government programs and initiatives**, coordinating activities between agencies and across communities. This collaboration builds strong road safety messages and achieves greater results by sharing resources.

Police and emergency services contribute valuable perspectives to the road safety issues in local regions.

ACRS provides **researchers and academics**, with a forum for discussion, advocacy and collaboration across disciplines, agencies and on an international scale.

How can you support the College and our work to reduce road trauma?

There are a variety of ways to showcase your support in reducing road trauma, including:

- **Membership**

All people and organisations are responsible for road safety and we encourage an inclusive environment via our diverse membership.

- **Sponsorship (e.g. events and awards)**

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- **Attending events**

A myriad of events are linked in the weekly e-newsletter - take your pick!

- **Registering as a Road Safety Professional**

By drawing on the Register of Road Safety Professionals, the College assists members with access to expertise such as expert witnesses for court proceedings and to field media enquiries.

To become a member, contact the College:

Australasian College of Road Safety
Ph: (02) 6290 2509

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Cover image

Traffic on a wet road – driving for work can expose workers to hazardous conditions. Image provided by CARRS-Q.

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The aim of the *Journal of the Australasian College of Road Safety* is to provide a medium for expression of views and debate on all facets of the study of road safety. Articles are accepted from a variety of disciplines, such as health and medicine, road and automotive engineering, education, law, behavioural sciences, communication, history, management, and urban and traffic planning. Interdisciplinary approaches are particularly welcome.

The College encourages interested persons and organisations to submit articles, photographs or letters for publication. Published

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Messages may be left on voicemail when the office is unattended.

From the President



Dear ACRS members,

Road safety management in public policy is something of a moving feast. In the last Journal I reported on our submission to all Federal politicians and the appointment of a new Ministry of Road Safety in the Federal Government.

Responses to our submission have been muted to say the least so far and we have at the week of writing a new Minister to fill the Road Safety Minister's position. We will be pleased to welcome the Hon Sharon Bird to the position.

The outgoing Minister did report on many actions underway within the National Road Safety Strategy to the Parliament and while we are pleased with her elevation to Cabinet, we will miss her enthusiasm and interest.

The Opposition Spokesman on Road Safety, Darren Chester, in response to the Minister, referred to many of the concepts raised in our submission to Parliamentarians; we will continue to brief him.

In the last month I had the opportunity to attend a large international conference on the Enhanced Safety of Vehicles in Seoul and also the first Towards Zero transport safety conference in Stockholm.

At both conferences there was a high level of active participation by a wide range of senior safety specialists including Ministers, government officers, academics and professionals from many transport fields; not just road and vehicle related areas. I was encouraged by new developments being reported which collectively have the potential to reduce unnecessary road trauma.

New collision avoidance technologies and new information systems are being rolled out not only for vehicles to assist the driving task, but also for train drivers. Industry is making great strides in road safety management, which will complement much of the good work undertaken by regulators and researchers. Equally there is an improved understanding and role of safety culture in a range of instances which may also help us to reduce road trauma.

However, collaboration between us all, particularly as members of the College should be an area where we can actually demonstrate the potential benefits of the safe systems approach. Looking outside our own specific area of interest though for new solutions always remains a challenge.

*Lauchlan McIntosh AM FACRS
ACRS President*

Diary

25 – 28 August 2013

T2013 International Conference
20th International Council on Alcohol, Drugs and Traffic Safety Conference
Brisbane Convention and Exhibition Centre, Brisbane
www.t2013.com

26 August 2013

A Comprehensive Road Safety Management Tool for Organisations - ISO 39001 (Workshop) Sydney
(see <http://www.arrb.com.au> for other State venues, dates and times)

28 – 30 August 2013

Australasian Road Safety Research, Policing and Education Conference 2013
Brisbane Convention and Exhibition Centre, Brisbane
<http://www.rsrpe2013.com.au/>

3 – 4 September 2013

Safety in Action 2013: Sydney Safety Conference
Sydney Showground, Sydney Olympic Park
<http://www.safetyinaction.com.au/safety-conference>

4 – 6 September 2013

3rd International Conference on Driver Distraction
Lindholmen Science Park, Gothenburg, Sweden

23 – 24 October 2013

Driving efficiency in road maintenance
Sydney Boulevard Hotel, Bayview Boulevard, Sydney
<http://roadefficiency.com/overview/>

6 – 8 November 2013

ACRS Conference
National Wine Centre of Australia
Adelaide
<http://acrs.org.au/conference/>

25 – 27 November 2013

Low Volume Roads Symposium, QLD 2013
Cairns Hilton Hotel, Cairns QLD
www.arrb.com.au/LowVolumeRoadsSymposium2013

Guest Editors



Mr Darren Wishart is a researcher in work related road safety with CARRS-Q and has considerable experience in work related road safety research and consultancy along with a Masters in Organisational Psychology. He has previous management experience in the private business sector, is a registered psychologist and

has operated as an organisational consultant to both public and private sector clients. He is the current Queensland Chapter Chair of the Australasian Fleet Management Association and is completing a PhD in work related road safety with CARRS-Q. Darren in recent years has delivered a series of capacity building road safety workshops in Indonesia and conducted numerous seminars, workshops and public speaking engagements on work related road safety within Australia.



Mr Bevan Rowland is a researcher in occupational safety and work-related road safety with CARRS-Q who has previously worked in the private and public sector nationally and internationally as a safety industry professional. Bevan's qualifications include a Bachelor of Further Education and Training at USQ, a Master of Health Science (Health,

Safety and Environment) and a Graduate Certificate in Road Safety at QUT. Currently, he is completing a PhD in the area of occupational road safety at QUT. He has been a long standing member, and committee member of relevant professional organisations namely the Safety Institute of Australia and Australasian College of Road Safety. In addition, he is a Chartered Professional Member of the Safety Institute of Australia (SIA), however is currently working through the SIA Chartered Fellow program.

Darren and Bevan's research involves working closely with stakeholders in the vehicle fleet industry to improve organisational driving safety through education, research, enhanced safety system management and benchmarking.

They were both also on the organising committee for the inaugural Occupational Safety in Transport Conference 2012 held on the Gold Coast and are currently in preparation to host the event for the second time in September 2014.

In Australia, the majority of locally produced passenger vehicles are purchased for work use and more than half of all new vehicle registrations annually are registered as fleet vehicles [1].

Occupational safety in transport is an area within road safety that is gaining increased attention due to the substantial physical, emotional, and economic costs to the community that are associated with work related road crashes. In Australia, work-related traumatic injury fatality figures indicate that over the last seven years two thirds of workers killed at work were the result of motor vehicle incidents [2]. The over representation of incidents involving vehicles would suggest that driving a vehicle for the purpose of work is likely to be one of the most at risk work activities that staff may perform in their daily work. Unfortunately despite the risk associated with work driving, the quality and extent of work-related road safety systems and practice within organisations is lacking and any vehicle management activities are primarily directed toward the asset in contrast to safety.

While health and safety legislation encompasses driving for the purpose of work, there is little evidence that government regulators practice effective enforcement in the area of work-related road safety. However, the responsibility does not lie solely with government regulators and requires a strong collaborative and committed approach involving all stakeholders, including but not limited to researchers, government, manufacturers and fleet industry users.

Although not all encompassing, this issue highlights various aspects related to occupational safety in transport. For example, this issue includes papers highlighting corporate road safety and the opportunities that exist for future improvement, a contrast of work related road safety within Australia and overseas initiatives and results of a study aimed at reducing workplace travel, and the organisational impact of attending and managing emergency responses to children accidentally locked in vehicles.

References

1. AFMA (2008). Review of the automotive industry 2008, submission by the Australasian Fleet Managers Association to the Australian Government. <http://www.afma.net.au/>
2. Safe Work Australia (2012). Work related traumatic injury fatalities, Australia 2010-11. Commonwealth of Australia.

Letters

Colleagues all,

I have recently returned from living and working as a road safety researcher in China for two years. Many of you have visited China, no doubt, and I know that some of you have had experiences working there. I want to share a few thoughts about my time in China and on the road safety situation in particular. I had the privilege of being the first International Visiting Scholar at the Zhejiang Police College in the city of Hangzhou in Zhejiang Province in China's south east for two years. Having lived in Beijing in China's north in 2008, being in the southeast was quite a different experience. The Zhejiang Police College is one of China's leading provincial level police training facilities and trains approximately 4000 undergraduate students each year and offers ongoing professional development to serving police, including some from the Tibet Autonomous Region. I was based in the Traffic Management Research Institute within the Department of Public Security and worked with the staff to help train Zhejiang's next generation of traffic police. Working on road safety in China brings specific challenges and opportunities. Admittedly, sometimes it is difficult to focus on the opportunities because of the enormity and complexity of the situation and the large trauma burden.

China weighs heavily on me for many reasons. The weight of welcome, friendship and hospitality is overwhelming. The weight of pressure on traffic police to perform their work with limited resources, little respect from the community and in difficult working conditions has had a lasting impact on me. The weight of national competing interests in a country ruled by a one-Party system is also overwhelming. I do not envy China's new leaders. President Xi Jinping has made it clear that the environment and corruption are two key areas of focus, both of which have links to road safety. Vehicle emissions feature heavily in the current air quality debate, particularly in the mega-cities of Beijing and Shanghai. Many Chinese citizens are, for the first time, financially able to purchase a car. Although driving remains a relatively unusual experience in many families, car ownership is skyrocketing, making China the largest car market in the world. Unfortunately, this new found 'freedom' adds significantly to problems of congestion and pollution. It also introduces more fast-moving vehicles into the fleet of relatively slow moving cycles - powered two and three wheelers and pedestrians.

I was often asked how Australia deals with the problems of congestion and pollution. How would you answer that question? Australia faces similar problems, but it is the sheer weight of numbers in China that should make us ask them how they manage the problems, so that we don't end up in the same boat in the future. New vehicle registrations

This is a picture of President Fu Guoliang of Zhejiang Police College, Dr Judy Fleiter of CARRS-Q and the graduating class of traffic police students, June 2012



are restricted in a few of the bigger Chinese cities at present. Try telling an Australian that they can't register their new car unless their number comes up in a monthly lottery (Beijing) or unless they can bid the highest amount in an auction (Shanghai). I sometimes contemplate whether I'll see such measures in Australia in my lifetime.

Lost potential also weighs heavily. Major loss of life among the most vulnerable (pedestrians, two and three wheeler riders) and the young is particularly hard to digest, especially when there are solutions that many countries, including Australia, have developed over many decades that may assist. The potential for savings by restraint and helmet use is enormous, yet use of these life-saving measures remains extremely low. Efforts are made to promote safer road use. The current Road Safety in 10 Countries (RS10) project operating in China is focussing on speeding and drink driving as key risk factors. I've been involved in that project through the World Health Organization and positive gains are evident, but a sense of urgency dwells in me that much more could and must be done. One of the main reasons for my optimism is that a variety of stakeholders are brought together in RS10 to communicate, develop, implement and evaluate road safety initiatives. This consultative process has been lacking in the past and will hopefully bring sustainable change to education and enforcement efforts.

'A drop in the ocean' is an apt summary of how I feel about the last two years working in China. The weight of all that I've shared, seen, learned and witnessed has left a greater sense of urgency in me as the Decade of Action rolls on. I am grateful for the marvellous opportunities I've had while living in China, yet also grateful to be back at CARRS-Q to continue my postdoctoral work that is funded by Australia's National Health and Medical Research Council Australia-China Exchange. I welcome contact from anyone interested in knowing more about road safety issues in China.

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Dear Editor,

Improving driving competence for drivers with new and renewed driver licences

The main component related to safe road traffic is the drivers. They are directly or indirectly responsible for the largest number of accidents and in around 50 % of all death accidents too high speed has been part of the reason for the accident. The education and training of responsible, careful drivers is therefore quite important. This also applies to the added education for those needing this during the lifespan

of the individual. The importance of this is illustrated by the fact that the lack of driving competence was part of the reason for more than 58 % of all death accidents in Norway during 2010.

The use of driving monitors in the vehicles may give valuable feedback to the individual under education. The thinking is to give the new driver a preliminary driving licence based on normal theoretical and practical education. For the next one to two years, the new driver is monitored by a GPS registration device in the dedicated vehicle to be used. This may start with an online monitoring of the driving. A supervisor is keeping track of the driving mode, given by the analysis of the driving. This can give compressed information about car speed related to allowed speed, fast acceleration and strong braking, side acceleration in turns, etc. The driver under learning will have full access to the data on a daily basis as well as the supervisor. Technically this equipment and software is available today.

Based on good progress, this monitor may be changed to a storage monitor for monthly control after some time, before the driver is given a full driver's licence. The 10 year renewing of the driver licence may be dependent on the driving record. With no fines or police records, this may be done with routine tests regarding new rules or similar. If the driver has one or more fines, the driving licence may be regarded as preliminary and subject to monitoring as for a new driver.

In the case of more than 'x' number of fines, the driver's licence may be made invalid before 10 years has passed and the driver has to take the driver's licence testing from the very beginning as would a new driver.

The main advantage with this procedure is the forcing of the driver to adapt safe and careful driving habits before a permanent driver's licence is given or renewed.

This driver monitoring system does allow for the detection of the breaking of speed limits. The handling of this has to be clearly described for the driver, the driver teacher and the police to ensure a uniform and accepted reaction. Further, the systems have to be designed to limit the possible misuse by manipulating the data system or data files.

Another problem which has to be taken care of is the correct updating of the speed limits along a large number of roads. A good system for updating of data maps with changes has to be included. Further an algorithm has to be developed to avoid speed data from crossing roads to be used. Due to possible mistakes in the data maps, the position of the vehicle at the points where measured speed is too high may therefore be stored. This would be to protect the driver from any consequence of this type of mistake with the data maps.

This system would further have to be evaluated by the Data Authority to safeguard the personal rights.

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Response:

The range of in-vehicle monitoring systems for young drivers seems to be ever increasing and so too are expectations that such systems will change behaviour and therefore solve the young driver crash problem – but is this valid? Certainly there are some great systems that can be very educational and improve driving performance in relation to things like taking corners too fast. Such systems therefore have the potential to benefit some young drivers – but how many? Does this mean the majority? There are several misconceptions in this field that the profession, including the College, could help address.

First, a major assumption behind many of the systems is that young drivers are wilfully reckless and it is their intentional risky driving behaviour that accounts for their over-representation in crashes. While it is difficult to quantify what proportion of the crash problem is due to such behaviour, this is true only of a minority of youth and likely only of a minority of their driving – not all. There is clear research evidence, including crash-based analyses, determining that lack of driving experience is the major contributing factor and more so than young age. Not all errors in judgement due to inexperience can be overcome by being monitored – in fact advanced passive vehicle technologies that correct for errors, such as electronic stability control and intelligent speed adaptation, are more clearly likely to be beneficial.

Second, who does the monitoring and how this is relayed back to the young driver will also impact on how effective monitoring systems might be. Many of the systems have the expectation that parents will review and take action on the monitored information. But this is simply not the case for many families – as keynote speaker, Dr Ann McCarrt, presented at the College Conference last year. Parents are busy and can't always keep up with the information provided or might choose not to or do so ineffectively. Decades of research on different parenting styles also suggest that how parents use the information will vary widely. The more one-sided, authoritarian approach that is demanding and punitive might result in little change once parents are no longer monitoring, whereas an authoritative approach that might still be demanding but collaborative and more likely to use the information in a training/ educational approach might be more effective.

In all, there is still a lot to learn about the best way to integrate such monitoring systems into current practices, accounting for a range of different family dynamics, and in ways that will improve and not impede or distract young drivers. Also, it is worth noting that the opening of the Letter to the Editor also presents a pre-safe system way of thinking of the crash problem. Drivers might be implicated in most crashes but they are one part of a system that also must rely on safe speeds, safe roads and roadsides, safe vehicles, and safe policies governing these, including strong graduated driver licensing systems that are currently the best known way to improve provisional driver safety.

Teresa Senserrick, PhD
Chair, NSW Chapter
Associate Professor, Transport and Road Safety Research,
The University of New South Wales

College news

National Office news

Welcome to new corporate members

Delta-B Experts Melbourne
 Eurobodalla Shire Council

Chapter reports

ACT and Region Chapter

Progress in the revitalisation of the ACT and Region Chapter has been very satisfying.

The Chapter achieved many of the objectives it had set for the past twelve months. The committee structure has worked well and in the last quarter we held two very successful seminars: the first on the *Culture of Speed in the ACT* and the second on *Trauma on ACT and surrounding NSW roads: How do we reduce it?*

Over 50 people attended each seminar and the feedback from participants was positive.

Our thanks go to ACRS members, Soames Job and Mary Sheehan, who participated as lead speakers in the seminars.

It was also very pleasing to have the support of many speakers from New South Wales in the rural road safety seminar – the NSW Roads and Maritime Services, NSW Police Force Traffic and Highway Patrol Command and the Yass Valley and Eurobodalla Shire Councils. Quite a number of rural local government road safety officers attended. This is an important part of our aim to have the Chapter become more active in the surrounding New South Wales region.

Conclusions and suggestions arising from the Culture of Speed in the ACT seminar were:

- A social connectedness exists between sustainable transport, health, environment, transport planning and the culture of speed and these need to be brought into sharper focus in overall planning to reduce road death and injury;
- While it is important to continue to ensure speed limits meet the requirements of Austroads Guides and the Australian Standards, more might be gained by highway safety reviews with a multi-disciplinary team reviewing serious crashes and the entire road, with a safe systems focus. Highway safety reviews provide better than black spot BCRs;
- Properly focussed enforcement is essential to successful reductions in speed related crashes;
- Emphasis on safe systems will provide a broader and better range of solutions than current approaches. In relation to speed, more emphasis needs to be placed on the safety aspects of road design and road furniture in the context of safe systems with a commitment to train sufficient personnel in the requirements of this evolving science.

The rural seminar considered that the following strategies and actions would bring about the best lasting results:

- *Reducing high speed crashes* is of paramount importance through a range of interventions: reduce secondary rural road speed limits to 90 or 80km/hr; well-targeted enforcement; introduction of speed limiters for repeat offenders; encourage the treatment of roads with design problems in areas of high speed crash possibilities; and the use of well-designed education programs particularly for male drivers.
- *Increased funding* for improvements of roads with a known crash record and the introduction of well-designed road design principles for such roads;

- *Maintain current successful programs* on the primary rural road system;
- *Undertake research* aimed at improving the safety of secondary roads in rural areas in the coming years;
- *Support well designed community based programs* which are based on community partnerships; interlinking government agencies; and effectively and efficiently deploying resources in the local community aimed at minimising road trauma on the local road network. The aim is to build upon local knowledge, experience and research to empower outcomes.

The Chapter has also been successful in obtaining ongoing support from the NRMA-ACT Trust for funding over the next two years. This will enable us to provide continuing public presentations on road safety issues to the ACT and surrounding New South Wales communities. One important objective is to build on the support of the Trust and to widen our funding base and industry assistance.

The program for 2013-14 will be drawn up at our next committee meeting on July 2.

As part of its aims to participate actively in the community, the Chapter has been engaged with the ACT Justice and Community Safety Directorate in a number of public consultation forums held to assist in the development of the ACT Road Safety Action Plan 2014-2107. Members attended all four sessions. The Chapter will continue to explore ways to assist in providing a means of linking the community to the Action Plan in the coming years.

In the immediate future, the Chapter has agreed to prepare a submission for the ACT Legislative Assembly's Inquiry into Vulnerable Road Users. The Chapter will seek advice from members in other Chapters on interventions which have been successful in this area.

Victorian Chapter

The Victorian Chapter has enjoyed a successful year, having staged four seminars. Seminars conducted covered the issues of local government's involvement in road safety, the graduated licensing system (GLS), fleet safety and a road safety hypothetical. Attendances have been in the range of 20-40 for each seminar, with the road safety hypothetical attracting in excess of 50 attendees. The Chapter is very grateful for the time and effort of presenters that have taken part in the seminars.

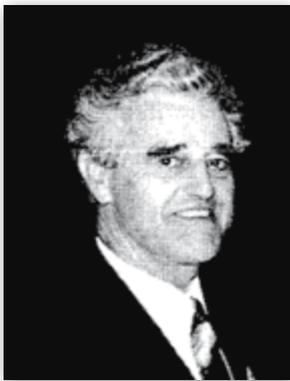
I would like to acknowledge the Victorian Chapter members who have all been a great support in assisting with College matters and preparation and delivery of seminars. We look forward to planning some more great seminars for the Chapter next year.

Jessica Truong
Victorian Chapter Chair

New South Wales (Sydney) Chapter

May was a busy month for the NSW Chapter with a Members Forum and Chapter Annual General Meeting held prior to the College AGM. The Members Forum proved a success with many and varied attendees and a wealth of ideas for seminars and other activities that the Executive is working to prioritise. We also led a proposal for changes to the Constitution that led to some amendments to revise out-dated details and streamline new processes.

These activities somewhat overshadowed another significant occasion for the Chapter, the College and Australasian road safety generally that deserves particular attention: the retirement from the Chapter Executive of Mr Harry Camkin.



Harry was the very first Fellow of the College, awarded in 1992, and justifiably so. Before the creation of the Roads and Traffic Authority of NSW (now Transport for NSW), management of road transport was fragmented. Harry was the head of the Traffic Authority of NSW and became head of both the

Traffic Authority and the Traffic Accident Research Unit in the early 1980's. Harry's leadership of the newly combined entity was instrumental in road safety gaining a stronger influence over policy in both the Department of Motor Transport and the Department of Main Roads.

Harry was always committed to road safety and enlisting collaborators. He presided over the first Australian road safety strategy that deliberately set out to be multi-agency and community focussed. He was a founding father of the now Australasian Road Safety Research, Policing and Education Conference, which has become one of the most significant road safety conferences in our region. On his retirement from the RTA, Harry pledged that he would make every effort to help the then fledging organisation: the Australasian College of Road Safety, to become great. He honoured that commitment.

This provides only a snapshot of Harry's influence on road safety in Australasia. I therefore speak on behalf of many in acknowledging and thanking Harry for his tireless commitment and efforts and wish him all the very best for the future.

*A/Prof Teresa Senserrick,
NSW (Sydney) Chapter Chair and Representative
on the Australasian ACRS Executive Committee*

Other news

Reports on managing young driver risk published

Road safety charity Brake has published two new reports for fleet managers on managing young driver risk.

The survey report and best practice guidance has been published alongside the first of four reports on a recent Brake survey of fleet managers, sponsored by Licence Bureau. Part one focusses on how young at-work drivers are managed. Both reports provide insight into the risks posed by employing novice drivers and advice on how to minimise those risks to maximise the safety of the whole fleet.

These publications are especially pertinent in light of the UK government's planned green paper on improving the safety of and reducing risks to young drivers, and Brake's recently-published survey results showing widespread public support for elements of graduated driver licensing

(GDL). As referenced in the guidance, elements of GDL can be adopted by fleet managers to improve the safety of young drivers.

Roz Cumming, professional engagement manager at Brake, said, "Fleet managers must be proactive in managing the risks associated with young drivers. This includes keeping an up-to-date record of drivers' ages, as well as detailed records of drivers' involvement in crashes. These reports highlight the importance of managing young driver risk and provide practical steps for fleet managers to follow."

From Fleet News, published June 19, 2013. <http://www.drivingforbetterbusiness.com/article.aspx?article=2015>

The Centre for Automotive Safety Research has released the following report which is available in full text online:

Post impact trajectory of vehicles at rural intersections

Web link: <http://casr.adelaide.edu.au/publications/list/?id=1370>

Report number: CASR086

Authors: Doecke SD, Mackenzie JRR, Woolley JE

Abstract:

This report describes the path of vehicles following a collision with another vehicle at a rural intersection. Detailed information from in-depth investigations of 70 intersection crashes was analysed. Rear end crashes at intersections were excluded as were collisions involving a motorcycle. The vehicle which had right of way most commonly had an impact speed of between 80 and 99 km/h and the impact point was on the front of the vehicle. The

vehicle which was required to give way most commonly had an impact speed of between zero and 20 km/h and was struck between the front of the vehicle and the B-pillar. After the vehicle to vehicle impact half the vehicles travelled more than 18 metres, 20% more than 34 metres and 10% more than 50 metres from the centre of the intersection. The most common direction of the vehicle following the initial impact was found to be between 15 and 29.9 degrees, where the original direction of travel of the through vehicle is at zero degrees. Intersection geometry, speed zone, impact point and mass ratio influence the nature of the post impact trajectory of the vehicles involved. As the results show a high number of vehicles travel a large distance at a shallow angle following an intersection collision, extending crash barriers on the through road (the road with right of way) right up to the intersection may have some benefit. Clear zones surrounding the intersection are also advisable and have an added benefit of increasing sight distance. Hazards can be assessed for removal or relocation by applying the results of this study.

Peer-reviewed papers

Work-related road safety in Australia, the United Kingdom and the United States of America: an overview of regulatory approaches and recommendations to enhance strategy and practice

by R Stuckey¹, SG Pratt², W Murray³

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Abstract

Work-related travel and transport by road is fundamental for industry, government and organisations. Traditionally, road safety interventions at societal level have focussed on improving road and vehicle engineering and changing road-user behaviour through transport laws and safety campaigns. Crash data indicate that significant numbers of road-user fatalities occur while driving to or for work. Therefore, workplace initiatives can improve both road and worker safety. This paper reviews regulatory approaches to work-related road safety (WRRS) in Australia, the United

Kingdom and United States, identifying significant and consistent gaps in policy, management and research. In all three countries, responsibility for managing and regulating WRRS is spread across government agencies, without a single coordinating body. This paper makes the case that integrating management of WRRS into regulatory and non-regulatory occupational health and safety (OHS) initiatives would foster and support collaboration between research and practice communities, ensuring a comprehensive evidence base for future programs.

Introduction

Road vehicles are driven for many purposes, ranging from social or domestic travel to use by commuters and workers in many occupations and industries. Historically, road transportation has been crucial to the development of industrial economies, with the rate of motor vehicle registrations seen as an important dimension of socioeconomic modernisation and political development [1]. Growing urbanisation results in greater demand for goods and services, and a corresponding increase in demand for freight transport. Economies of scale have resulted in increasingly larger freight vehicles and smaller and more economical light vehicles. Contemporary work patterns have increased the demand for mobile and accessible workers using vehicles equipped with portable facilities to enable peripatetic work away from employer-controlled work sites [2, 3].

Motor vehicle crashes (MVCs) are consistently the leading cause of traumatic work-related fatality and injury in most westernised countries [4, 5]. In Australia, MVCs in traffic accounted for 24% (n=53) of all work-related fatalities from July 2010 through June 2011, and MVCs during commuting resulted in another 110 fatalities [6]. In the United States (U.S.), MVCs in the course of work (on or off public roads, but excluding commuting) accounted for 35% of all occupational fatalities in 2011. Driver-sales workers and truck drivers accounted for 33% of these, with the remainder distributed across all other occupational groups [7]. In the United Kingdom (UK), excluding Northern Ireland, work-related crashes made up 29% of all road traffic fatalities in 2011 and an additional 12% of road traffic fatalities occurred while commuting to or from work [8].

Over the past decade, work-related road safety (WRRS) has gained increased international recognition. In 2008, the United Nations (UN) General Assembly adopted a resolution on ‘Improving Global Road Safety,’ which *‘Encourages organizations in both the private and the public sector with vehicle fleets, including agencies of the United Nations system, to develop and implement policies and practices that will reduce crash risks for vehicle occupants and other road users’* [9]. This UN resolution notes the global importance of vehicle operations to worker and public safety, and justifies action by corporations, governments and other stakeholders to improve road safety for workers. Further, the formal plan for action for the UN Decade of Action for Road Safety 2010-2020 includes numerous elements relevant to WRRS [10].

WRRS encompasses a complex mixture of roads, users and vehicles of all types and sizes. The exposed population includes all users of work vehicles: drivers and passengers of trucks, buses, taxis, courier vehicles, hire-cars, emergency service vehicles, cars, two-wheelers and other

light vehicles. Many such workers use vehicles as a ‘tool’ in the course of employment, but their occupational title is not necessarily ‘driver.’ Although the legal scope and definitions vary by jurisdiction, often related to insurance and workers’ compensation schemes, the significant risks involved in commuting should also be seen as a key element of WRRS.

This paper reviews regulatory approaches to WRRS in Australia, the UK and the U.S., and provides recommendations for the development of systematic and strategic responses for policy, research and workplace practice.

Regulation and the operating environment

Australia

In Australia, the regulating entity for heavy vehicles, the National Transport Commission (NTC), works with peak industry bodies and government to develop land-transport policy and is responsible for many safety and compliance issues, including the review of medical standards for assessing fitness-for-duty for commercial vehicle drivers (Table 1). NTC commercial vehicle driver standards apply to bus, taxi and small bus drivers, chauffeurs and those authorised to carry bulk dangerous goods. The 2012 national Work Health and Safety Regulations cover workplace hazardous substances and dangerous goods under a single framework which includes the NTC’s Australian Dangerous Goods Code Road and Rail [11]. Additionally, each Australian State and Territory has its own local vehicle and driver registration agency and OHS regulator.

In 2001, a landmark review of long-haul trucking recommended increased harmonisation between road transport and OHS legislation and greater interagency cooperation to address serious concerns about trucking safety [12]. Subsequent reforms to national road-transport laws introduced requirements that hold all those with control over a heavy-vehicle user’s ability to comply with relevant regulations both accountable and responsible if they fail to discharge that responsibility. In addition to drivers and employers, this ‘chain of responsibility’ includes organisers of trip schedules, consignors, importers, retailers and primary producers [13]. In 2012, a single national system framework, the Heavy Vehicle Regulatory Reform, was put in place to regulate all vehicles over 4.5 gross tonnes [14].

Table 1. Australian federal agencies with responsibility for work-related road safety

Agency	Ministry	Notes
Transport Agencies		
National Transport Commission (NTC)	Department of Infrastructure and Transport	<ul style="list-style-type: none"> • Administers Australian Design Rules (ADRs): all road vehicles required to comply at the time of manufacture • Administers Australian Dangerous Goods Code • Works in partnership with peak industry bodies and government to develop heavy vehicle land-transport policy • Reviews medical standards for assessing fitness to drive for commercial vehicle drivers
Austroroads	None: Comprised of Australian and New Zealand road transport and traffic authorities (including the Department of Infrastructure and Transport)	<ul style="list-style-type: none"> • Provides expert technical input to national policy development on road and transport issues • Promotes consistency in road and road agency operations • Promotes improved practice and capability by road agencies
OHS Agencies		
Safe Work Australia	Intergovernmental Agreement for Regulatory and Operational Reform in Occupational Health and Safety	<ul style="list-style-type: none"> • Federal policy-setting body whose role is to improve OHS and workers' compensation arrangements across Australia • Recognises work vehicles as a workplace on public roads • Collates work-road and other work related data • Current WRRS Guides published by WorkSafe Victoria

Under the Australian Work, Health and Safety Act 2011, vehicles used for the purpose of work are classified as a 'workplace.' To date, however, this national legislation has not been fully adopted by all states in Australia [15]. Employer obligations to ensure a safe place of work apply to potential risks within the work-vehicle environment and the roads on which employees are driving. All at-work drivers must comply with jurisdictional road safety legislation including requirements relating to speeding, mobile-phone use, seatbelt-use, alcohol and drugs. In addition, there are obligations under all Australian OHS Acts to ensure workers are fit to drive, both cognitively and physically, including requirements to report any ongoing illness likely to affect the ability to drive safely. If a driver is impaired, formal assessment of fitness to drive is undertaken according to two sets of medical standards: commercial vehicle driver standards, or private driver standards, which apply to all other motorists [16]. Other than generic vehicle requirements for roadworthiness and registration, and responsibilities for the transport of Dangerous Goods [11], there are no specific standards prescribed for light vehicles; the standard for light vehicles is the possession of a current driving licence, regardless of driving competence, experience or the work context.

United Kingdom (UK)

Since the Second World War, various Transport Acts have regulated the heavy-truck and bus sectors, focusing on areas such as vehicle weights, drivers' hours and licencing, and certification of professional competence. Lighter vehicles used for work purposes, including cars and vans, have remained relatively unregulated beyond the Highway Code and general rules of the road. The OHS agency, the Health and Safety Executive (HSE), was created by the 1974 Health and Safety at Work (HSW) Act. The HSE does not exercise its jurisdiction for crashes on public roads, nor does it include them in its data collection on work-related injuries. Generic concepts within the HSW Act are nonetheless relevant to WRRS, notably 'duty of care,' which charges an employer to '*ensure, so far as is reasonably practicable, the health, safety and welfare at work of all his employees*' (Part I, Section 2 (1)) [17]. This provision has been used to argue that employers' responsibility to provide a safe work environment ought to extend to all workplaces, including motor vehicles.

Because HSE regulations are not directly enforced for at-work driving, basic legislation under the Department for Transport (DfT) has become the de facto source of law for work-related driving in the UK. The Road Transport Act (RTA) of 1988 covers licencing for all classes of

Table 2. British government agencies with responsibility for work-related road safety

Agency	Ministry	Notes
Transport Agencies		
Department for Transport (DfT)		<ul style="list-style-type: none"> Oversees the work of public agencies that cover all modes of transport Transport Statistics unit publishes road crash statistics for Great Britain
Driving Standards Agency (DSA)	Department for Transport	<ul style="list-style-type: none"> Sets driver testing standards, including those for the EU-mandated Certificate of Professional Competence (CPC) to drivers of large-goods and passenger transport vehicles Conducts written and on-road driving tests Regulates driving instructors
Driver and Vehicle Licensing Agency (DVLA)	Department for Transport	<ul style="list-style-type: none"> Issues driving licences, including special endorsements, and vehicle registrations Agency to which licenced drivers must report medical conditions affecting their ability to drive Dependent on fully informed, explicit and freely given driver consent, DVLA sells licence endorsement data for entitlement and risk management purposes
Vehicle and Operator Services Agency (VOSA)	Department for Transport	<ul style="list-style-type: none"> Enforces safety standards for large-goods vehicles and passenger-transport vehicles Supports work of regional Traffic Commissioners, who review applications and issue the EU-mandated CPCs to companies that transport passengers or freight For all types of vehicles: <ul style="list-style-type: none"> Oversees vehicle inspection programs and enforcement of manufacturing standards Investigates vehicle defects and issues recalls
OHS Agencies		
Health and Safety Commission (HSC)	Independent commission	Sets policy for OHS
Health and Safety Executive (HSE)	Not attached to a ministry	<ul style="list-style-type: none"> Implements and enforces OHS regulations Investigates occupational injuries on employer premises

drivers, manufacturing standards, seat-belt use, impaired and reckless driving, vehicle inspections, fitness to drive, and loading of goods vehicles. Other RTA provisions hold employers and other parties partially responsible for certain road infractions [18]. Since the UK joined the European Union (EU), regulations for heavy vehicles have increasingly been intertwined with EU initiatives covering areas such as working time, driver licencing and driver training via the Certificate of Professional Competence (CPC). To date, EU directives and regulations have not explicitly included the significant numbers of light vehicles being driven for work. However, the 1989 'Framework Directive' for OHS emphasised the employer's responsibility to 'evaluate the risks to the safety and health of workers, inter alia in the choice of work equipment, the chemical substances or preparations used, and the fitting-

out of work places' (Article 6(3)a) [19]. As a directive, this EU legislation charged member states to develop conforming national legislation.

Several high-profile transportation disasters in the 1990's drew the attention of UK policymakers and the public to WRRS. In 1996 and 1997, the Royal Society for the Prevention of Accidents (RoSPA) organised stakeholder meetings around the question of whether employer 'duty of care' under the HSW Act should extend to work-related driving. Arguments in favour of employers taking responsibility for managing WRRS for light as well as heavy vehicles were bolstered by the EU Framework Directive's requirement that employers conduct comprehensive risk assessments. The RoSPA-sponsored meetings led to a consensus that businesses ought to

institute policies and procedures to manage road risk and participants signed a declaration to that effect [20].

In response, a broad-based committee convened by the government recommended that employers manage at-work road risk within the framework that should already be in place for managing all other OHS risks [21]. In 2003, the HSE and DfT jointly issued a guidance document called *Driving at Work* [22]. Although this did not have the force of regulation, it was nonetheless symbolically important because it represented an official entrance into the WRRS policy area by HSE. Moreover, it has come to be accepted as setting core requirements to be followed by organisations, and it applies to all vehicles used for work purposes irrespective of type, size or ownership.

More recently, the 2007 Corporate Manslaughter and Homicide Act allowed criminal negligence lawsuits against businesses when management's failure to exercise its 'duty of care' results in death. The law is intended to complement

other legal remedies, including OHS regulations. Lawsuits brought under this law are handled as criminal cases, not labour action [23]. Today, a number of British government agencies under the DfT have responsibilities relevant to WRRS. Many have dual responsibility for managing the same issues for work-related driving and the general motoring public (Table 2).

A growing body of collaborative research from the UK has established risk factors associated with driving for work, the importance of identifying at-risk drivers, and the role of fleet management programs in reducing crash rates. Government-sponsored research [24-27] has allowed the government to be indirectly involved in building the knowledge base for WRRS without imposing new government mandates. Purpose-of-journey data from transportation statistics have identified crash-involved work vehicles by type, which may lead to more effective targeting of interventions [28]. Organisational-level research has focused on driver assessment and improvement

Table 3. U.S. federal agencies with responsibility for work-related road safety

Agency	Ministry	Notes
Transport Agencies		
Federal Highway Administration (FHWA)	Department of Transportation	Issues Manual on Uniform Traffic Control Devices (MUTCD), which provides guidance for setting up highway construction work zones and managing special situations including crash scenes
Federal Motor Carrier Safety Administration (FMCSA)	Department of Transportation	<ul style="list-style-type: none"> • Develops and enforces safety regulations for all aspects of large-truck and bus operations • Oversees monitoring of carriers' safety performance and roadside inspections of large trucks and buses • Oversees Commercial Driver's License (CDL) program • Medical Program: rules to ensure that physical qualification of drivers reflects current clinical knowledge and practice
National Highway Traffic Safety Administration (NHTSA)	Department of Transportation	<ul style="list-style-type: none"> • Issues the Federal Motor Vehicle Safety Standards (FMVSS) applicable to all vehicles manufactured for sale or use in the U.S. • Investigates vehicle defects and issues recalls • Collects and maintains national databases on fatal and nonfatal MVCs
OHS Agencies		
Occupational Safety and Health Administration (OSHA)	Department of Labor	<ul style="list-style-type: none"> • Develops federal OHS regulations and enforces them in cooperation with states • Limited regulations for motor vehicle operations • Investigates occupational injuries on employer premises
Bureau of Labor Statistics (BLS)	Department of Labor	<ul style="list-style-type: none"> • Collects occupational injury and fatality data in cooperation with states (commuting-related incidents are excluded)
National Institute for Occupational Safety and Health (NIOSH)	Department of Health and Human Services	<ul style="list-style-type: none"> • Conducts research and makes recommendations for preventing occupational injuries and illnesses, including motor vehicle-related injuries

to help develop a culture of safe driving and reductions in crash rates and costs via a comprehensive fleet safety program [29, 30]. Although a systems-based approach is widely advocated in the UK, researchers have also noted the challenges of assessing the effects of ‘packages’ of individual interventions [31].

United States

In the U.S., workplace driving takes place in two distinct settings: the U.S. Department of Transportation (DOT) regulatory regime that covers large trucks and buses, and the largely unregulated operation of light vehicles driven for work. Regulations to promote safe operation of large trucks and buses have been part of U.S. federal policy since the 1930’s. Today, this regulatory responsibility is carried out by the Federal Motor Carrier Safety Administration (FMCSA) in the U.S. Department of Transportation. FMCSA’s primary mission is to ensure the safe operation of large trucks and buses, primarily by promulgating and enforcing safety regulations (<http://www.fmcsa.dot.gov/rules-regulations/rules-regulations.htm>). Although development and oversight of these regulations occurs at federal level, licencing under the Commercial Driver’s License (CDL) program and most enforcement activities are carried out by the states. FMCSA also supports research and non-regulatory safety initiatives related to new technology, management practices, and driver behaviour (Table 3).

In contrast, there are no corresponding regulations applicable to U.S. workers who drive light vehicles for work purposes. At-work driving falls under the Occupational Safety and Health Administration (OSHA) ‘general duty clause,’ which requires an employer to provide ‘*employment and a place of employment which are free from recognized hazards that are causing or are likely to cause death or serious physical harm to his employees*’ [32]. OSHA has issued regulations covering some aspects of mobile equipment operation in construction, logging, marine terminals and agriculture. OSHA has no regulations for operation of motor vehicles on public roadways that cover a wide range of vehicles, drivers and work situations (Table 3). The OSHA policy response to occupational risks of light-vehicle operation has included voluntary initiatives, guidance documents, ad hoc advisory committees and a recent enforcement initiative on distracted driving that uses the ‘general duty clause’ as the basis for action [33]. Operation of most vehicles in the U.S. workplace is in effect governed by traffic laws, augmented by employer policies. In the U.S., laws related to mobile-phone use, seat belts, speed limits, age of licensure, and licence renewal are the responsibility of individual states. Inconsistency in laws and regulations from state to state can complicate road safety management for organisations that operate in multiple states.

Fatality risk is consistently highest in the truck transportation sector. For this reason, the vast majority of U.S. literature on WRRS addresses known and hypothesised risk factors for truck drivers, including driver fatigue and hours of service [34-36], medical conditions [37-40] and use of mobile devices [41, 42]. Published research on the safety of light vehicles driven for work is limited. Reports published in the last decade have addressed MVCs among law enforcement officers [43]; home healthcare workers [44]; workers operating agricultural equipment on public roadways [45, 46]; and workers in the oil and gas extraction industries [47]. One of the few U.S. studies to assess the effectiveness of behavioural interventions was a series of related experiments conducted over many years among pizza delivery drivers [48].

Discussion and recommendations

This review revealed significant and consistent gaps in WRRS policy and research. In all three countries, responsibility for managing and regulating WRRS is spread across government agencies, with no single policy-coordination body. In both Australia and the U.S., the presence of federal, state and territorial jurisdictions is a complicating factor because responsibility for legislation, regulation and enforcement is divided or shared among these levels of government. This may create obstacles to identifying hazards and exposures for all vehicle types, and to establishing coordinated and effective risk management systems; policy, research, and enforcement initiatives; and data systems.

In all three countries, regulations for commercial heavy vehicles that transport freight and people are well-developed, with responsibility assigned to road safety and transport agencies. In contrast, the safety of workers using light vehicles for work purposes is not fully addressed by OHS and transport regulations. In Australia, OHS policy formally recognises all types of work vehicles as workplaces and MVCs are included in data systems on work injuries. In the UK, OHS policy includes the former but not the latter, although public-private cooperative efforts to improve WRRS are otherwise strong. In the U.S., OHS data include at-work MVCs, but light vehicles are not explicitly recognised as workplaces for OHS enforcement purposes, except under general laws that require employers to provide a safe work environment.

Based on the evidence presented, it may be beneficial to conceptualise management of WRRS as an integral part of regulatory and non-regulatory OHS initiatives. For example, the recent adoption of ‘Model WHS legislation’ across nearly all national jurisdictions in Australia provides a unique opportunity to improve regulatory standards [49]. Other government-led strategies might include recommended core data collection elements, key performance indicators, evaluation methods for use by

public and private sector organisations, and case examples that demonstrate the cost-effectiveness and economic benefits of WRRS programs.

Governments can also foster information exchange between the research and practice communities, which is beneficial to ensuring a comprehensive evidence base to support future policy and practice. Cooperative, non-regulatory initiatives have mushroomed in recent years, e.g., Driving for Better Business (DfBB) in the UK, the Network of Employers for Traffic Safety (NETS) in the U.S., compliance assistance offered to employers in Australia through the Transport Accident Commission/Worksafe, the growth of the Work-related Road Safety Project Group in the UN Road Safety Collaboration, and major road safety conferences worldwide that have wholly or in part addressed WRRS. In addition, stakeholders have developed resources to help organisations manage risk (Appendix 1), which demonstrates the increasing importance ascribed to WRRS and the benefits of cooperation among stakeholders.

In all three countries, many public and private sector employers have recognised the burden of work-related MVCs on their organisations and their workers, and have integrated road safety into OHS risk-management processes. However, in some organisations, awareness of the burden and the implementation and evaluation of countermeasures are not well-developed. For all organisations whose employees drive for work, WRRS is a key component of OHS risk-management systems. Successful implementation requires worker and management commitment, identification of risks and related hazards and exposures, implementation of appropriate control strategies and collection of data to assess risk and track progress [50]. Control strategies should be based on hierarchical approaches, recognising that the vehicle is work equipment and the road part of the work environment. Engineering controls should include the use of evidence-based vehicle selection resources such as New Car Assessment Programs and managed maintenance and procurement programs. Engineering controls should be supported by safe-driving policies, with strategically supported trip management (e.g., accommodation on long trips) and restrictions on use of technology such as mobile phones. In addition, the new International Organization for Standardization (ISO) 39001 standard on road traffic safety management systems provides an opportunity to engage organisations across all the locations in which they operate [50].

The lack of peer-reviewed outcome evaluations is a major WRRS research gap. While employers are being encouraged to implement comprehensive fleet safety programs, the evidence base supporting the efficacy of specific program elements is limited. Within WRRS, the following types of research are urgently needed:

- Formal evaluations by organisations with existing ‘good practice’ projects (e.g., Fleet Safety Benchmarking, NETS, and DfBB).
- Collaborations between organisations and researchers to evaluate the success of road safety interventions (e.g. peer reviewed studies based on road safety outcomes, involving suppliers of behind-the-wheel training or driver assessment and monitoring systems).
- Use of workers’ compensation, social, or general fleet insurance data and resources to target risks associated with work-related driving and commuting.
- Research and demonstration projects focussing on the links between safety, operational efficiency and the environment.
- Studies on structural issues such as excess working hours, unrealistic delivery schedules, the growing home delivery and courier sectors, peripatetic light vehicle users and load piece rate payment systems.
- Research on working conditions where contracting, subcontracting and use of temporary labour are common, to better determine the impact of organisational characteristics on worker health and suggested potential interventions throughout the supply chain.

Several fundamental principles can be consistently applied regardless of country, agency or stakeholder, including: (1) recognition of all types of vehicles as workplaces when they are driven for work purposes; (2) implementation of inclusive and consistent definitions encompassing all users and types of work vehicles and work situations; and (3) development of clear duty-of-care obligations for all at-work drivers, their employers and others, consistent with existing risk-management systems for heavy vehicles such as Australia’s ‘chain of responsibility’ system [13]. These obligations should include strategies to manage fitness-for-task requirements and the introduction of OHS-related standards.

The UN Decade of Action for Road Safety holds great promise for drawing international attention to WRRS. Engagement of private and public sector organisations to prevent work-related crashes for their own workforces can influence a significant component of global road risk. WRRS has many stakeholders: government agencies responsible for transport, OHS, and public health; public and private fleet owners; labour; researchers; and international organisations. Further collaboration across all stakeholder groups may lead to more effective control systems to manage the human, financial and community risks – applying a risk-led systems-based approach.

Conclusion

Based on crash and injury data, the safety of persons who drive for work is a significant issue for the OHS and road-safety policy communities. Employers, governments, and other stakeholders are therefore presented with the challenge and opportunity to address road safety risks for these workers via their workplaces. This paper has described regulatory approaches to WRRS in Australia, the UK and the U.S. and offered recommendations for developing systematic and strategic responses for policy, research and workplaces. The adoption of an OHS-centred and evidence-based approach to WRRS offers the potential to address this significant societal issue. Interventions to address identified risks could reduce human harm while assisting organisations to be safer, more profitable and efficient, with enhanced reputation within their community. Governments, researchers and key stakeholders in organisations requiring their people to travel to or for work are encouraged to undertake efforts to understand, manage and minimise the risks. WRRS is a significant OHS and road-safety issue which is appropriately addressed by government, regulators and other stakeholders in a coordinated and systematic manner. Coordinated policy and practice may reduce the number of workers and others who are likely to be injured or killed while using public roads.

The findings and conclusions in this report are those of the authors and do not necessarily represent the views of the National Institute for Occupational Safety and Health and Centers for Disease Control and Prevention.

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Appendix 1: Workplace practice and resources

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United Kingdom
<p>Brake: Road safety charity that offers fleet safety resources: http://www.brake.org.uk/Department for Transport:</p> <ul style="list-style-type: none"> • A DfT guide to work-related travel (2011): http://webarchive.nationalarchives.gov.uk/20111005181249/http://www.dft.gov.uk/publications/measuring-and-reporting-greenhouse-gas-emissions • Toolkit for assessing and managing occupational road risk (2004): http://webarchive.nationalarchives.gov.uk/20090210013353/http://www.dft.gov.uk/pgr/roadsafety/research/rsrr/theme2/safetycultureandworkrelate51.pdf <p>Health and Safety Executive:</p> <ul style="list-style-type: none"> • Work related road safety (2013): http://www.hse.gov.uk/roadsafety/ • Driving at work: managing work-related road safety (2003): http://www.hse.gov.uk/pubns/indg382.pdf <p>Interactive Driving Systems (2013):</p> <p>Fleet Safety Benchmarking: Web site to help companies and organisations that run vehicle fleets to effectively manage road risk. Includes free fleet safety gap analysis and case studies. Royal Society for the Prevention of Accidents (RoSPA). Guidance documents on impaired driving, mobile phones, in-vehicle technology, speed management and road safety for volunteer workers: http://www.rospace.com/roadsafety/resources/employers/</p> <ul style="list-style-type: none"> • Driving for work: Fitness to drive (2007): http://www.rospace.com/roadsafety/info/workfitness.pdf • Young Drivers at Work project materials (2008): http://www.rospace.com/roadsafety/youngdriversatwork/default.aspx • Vehicle technology: A manager's guide (2008): http://www.rospace.com/roadsafety/info/vehicle_technology.pdf • Managing occupational road risk: advice for SME's (2009): http://www.rospace.com/roadsafety/info/morr_sme.pdf <p>RoadSafe (2013):</p> <ul style="list-style-type: none"> • Driving for Better Business: program to develop and coordinate a network of employers and champions to promote good practice in work-related road safety. • Global compilations of employer resources on work-related road safety are available on the FleetSafe page: (see Employer Road Safety Processes, Procedures and Programs and International Web-based Resources)

United States
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FMCSA:
<ul style="list-style-type: none">• Cross-border safety, inspection, and collision statistics by their country of domicile, for registered intrastate and interstate motor carriers operating in the United States: http://ai.fmcsa.dot.gov/international/border.asp• CMV Web-based Driving Tips: collection of defensive driving tips focusing on common driving errors made by commercial vehicle drivers: http://www.fmcsa.dot.gov/about/outreach/education/driverTips/index.htm• Safety is Good Business: resources to help motor carriers better understand business responsibilities and economic benefits of safety: http://www.fmcsa.dot.gov/safety-security/good-business/index.htm• Safety Belt Partnership: initiative to increase use of seat belts among drivers of large trucks and buses: www.fmcsa.dot.gov/safety-security/safety-belt/index.htm
Network of Employers for Traffic Safety (NETS): www.trafficsafety.org
National Institute for Occupational Safety and Health (NIOSH): http://www.cdc.gov/niosh/topics/motorvehicle
National Safety Council (NSC):
<ul style="list-style-type: none">• ‘Cell Phone Policy Kit’ (free for download) and other distracted-driving resources for employers:<ul style="list-style-type: none">• http://shop.nsc.org/NSC-Cell-Phone-Policy-Kit-Downloadable-P2222.aspx• http://www.nsc.org/safety_road/Distracted_Driving/Pages/EmployerPolicies.aspx• Our Driving Concern: a comprehensive safety manual for use by organisational fleet managers, with numerous checklists and sample policies as well as articles on topics such as distracted driving:<ul style="list-style-type: none">• http://www.nsc.org/safety_road/EmployerTrafficSafety/Pages/NationalHome.aspx
Occupational Safety and Health Administration (OSHA): http://www.osha.gov/SLTC/motorvehiclesafety/index.html
Transportation Research Board (TRB): produces succinct reviews of a wide range of trucking health and safety topics such as driver wellness, fatigue management, driver selection, and management practices: http://www.trb.org/Publications/PubsCTBSSPSynthesisReports.aspx
U.S. Department of Transportation initiative on distracted driving. Role of employer policies in reducing distraction-related crashes, and materials to encourage employer and employee involvement: http://www.distraction.gov/content/get-involved/employers.html

Effects of mobile phone distraction on drivers’ reaction times

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Abstract

Distraction resulting from mobile phone use whilst driving has been shown to increase the reaction times of drivers, thereby increasing the likelihood of a crash. This study compares the effects of mobile phone conversations on reaction times of drivers responding to traffic events that occur at different points in a driver’s field of view. The

CARRS-Q Advanced Driving Simulator was used to test a group of young drivers on various simulated driving tasks including a traffic event that occurred within the driver’s central vision - a lead vehicle braking suddenly; and an event that occurred within the driver’s peripheral vision - a pedestrian entering a zebra crossing from a footpath. Thirty-two licenced drivers drove the simulator in three phone conditions: baseline (no phone conversation),

and while engaged in hands-free and handheld phone conversations. The drivers were aged between 21 to 26 years and split evenly by gender. Differences in reaction times for an event in a driver's central vision were not statistically significant across phone conditions, probably due to a lower speed selection by the distracted drivers. In contrast, the reaction times to detect an event that originated in a distracted driver's peripheral vision were more than 50% longer compared to the baseline condition. A further statistical analysis revealed that deterioration of reaction times to an event in the peripheral vision was greatest for distracted drivers holding a provisional licence. Many critical events originate in a driver's periphery, including vehicles, bicyclists, and pedestrians emerging from side streets. A reduction in the ability to detect these events while distracted presents a significant safety concern that must be addressed.

Keywords:

mobile phone distraction; advanced driving simulator; driver reaction times; young drivers; peripheral vision, road safety

Introduction

Mobile phone distraction

The widespread use of mobile phones whilst driving has become a serious public health threat and is linked to an increased risk of involvement in road crashes. Mobile phone distraction alone claimed about 995 lives and another 24,000 injuries on US roads in 2009 [1]. An epidemiological study indicated that distraction resulting from mobile phone conversations quadrupled the crash risk of drivers [2]. Violanti and Marshall [3] reported similar findings where drivers talking more than 50 minutes in a vehicle were associated with a 5.6 fold increase in crash risk.

A significant safety concern is that the use of mobile phones while driving is more prevalent in younger and less experienced drivers; a driving cohort with elevated crash risk. An Australian study reported that among 2400 driving distraction-related incidents in New South Wales, young drivers had the highest frequency of mobile phone use-related injurious crashes [4]. Horberry et al. [5] reported that more than 60% of drivers who use a mobile phone whilst driving were less than forty years old. A recent survey [6] reported that almost one in two Australian drivers aged between 18 to 24 years used a handheld mobile phone while driving, nearly 60% of them sent text messages and about 20% of them read emails and surfed the internet.

The use of a mobile phone while driving influences numerous common driving behaviours, including a deterioration of speed control, speed reductions, a failure to maintain appropriate headway, an increase of the

variation of lane position, a limitation of peripheral eye scanning, a decline in braking performance, and impairment in the perception of relevant stimuli [7]. Rakauskas et al. [8] reported that mobile phone use caused drivers to have higher variation in accelerator pedal position, drive slowly with more speed variation and report a higher workload. Tornos and Bolling [9] studied the effects of phone conversation using the VTI driving simulator II and observed risk compensation behaviour, where drivers tended to reduce their speed while talking on the phone. Using a desktop driving simulator, Dula et al. [10] reported that driving tasks like percentage of time spent speeding and centre line crossings were significantly different among drivers engaged in different types of conversations in comparison to no conversation.

Reaction times of distracted drivers

A mobile phone conversation distracts drivers by shifting their attention away from the primary driving task. As such, the reaction times of drivers has been of research interest - as a surrogate measure of the crash risk of mobile phone conversation - and under various study situations including laboratory, driving simulator, and in-field trials. Consiglio et al. [11] examined the braking performances of distracted drivers upon the activation of a red lamp in a laboratory and found that both hands-free and hand-held mobile phone conversations resulted in slower reaction times in performing the braking task. Slower responses of distracted drivers were also observed in a desktop simulator experiment where drivers tended to take one-third of a second longer to begin driving from a stop sign while engaged in a phone conversation [12]. Using an advanced driving simulator, Tornos and Bolling [9] examined the reaction times of distracted drivers in a peripheral detection task (PDT) under various environmental complexities, and reported that the PDT response time was longer and accuracy was worse in mobile phone conditions, irrespective of phone type and environmental complexity. Similarly, Amado and Ulupinar [13] reported that mobile phone conversations had negative effects on attention and peripheral detection of stimuli. An in-field experiment on the stopping decisions of a group of mobile phone distracted drivers, where participants were instructed to perform a quick stop before reaching the stop line of an intersection upon the onset of a red light, showed that the non-response to a red light increased by 15% on average among distracted drivers [14].

Conversations using either hands-free or handheld mobile phones had been found to impair the reaction times of drivers more than driving under the influence of alcohol at the 8% or 0.08gm/100ml legal limit [15]. A meta-analysis conducted on 33 studies, by Caird et al. [16], reported a 0.25 second increase in reaction time for all types of phone-related tasks and both hands-free and handheld phone conversations had similar effects on reaction

times. Another meta-analysis of 23 studies revealed that mobile phone distraction increased the response times to unexpected hazards with similar effects for both hands-free and handheld phone conditions [17]. A recent review by Ishigami and Klein [18] reported a similar conclusion of slower reaction times of distracted compared to non-distracted drivers.

Several studies have examined the reaction times of distracted drivers across age and gender. The reaction times of older drivers appeared to be impaired by 0.29 seconds by a mobile phone conversation, while the corresponding impairment of young drivers was only 0.11 seconds - less than half of older drivers [14]. Similar reaction time impairment was reported by Caird et al. [16], where the reaction times were 0.46 seconds and 0.19 seconds slower, respectively, for distracted older and young drivers. An experiment on an advanced driving simulator by Nilsson and Alm [19] showed that elderly drivers' reaction times to an unexpected event was approximately 0.40 seconds greater than for young drivers when distracted by a mobile phone conversation. Research on the effects of gender showed that mobile phone distraction had a greater influence on females than males with corresponding impairments of 0.25 seconds and 0.14 seconds respectively [14].

The human brain manages all tasks needed for driving including visual, auditory, manual and cognitive. An analysis using the functional magnetic resonance imaging (fMRI) showed that mobile phone distraction requiring the processing of auditory sentences decreased the brain activity as much as 37% of the critical tasks associated with driving [20]. The increased cognitive load of a mobile phone conversation might cause a withdrawal of attention from the visual scene - where all the information a driver sees is not processed - yielding a form of inattention blindness [21]. In other words, the human brain compensates for receiving increased information by not sending some visual information to the working memory, leading to a tendency to 'look at' but not 'see' objects by distracted drivers [22]. The effect of a mobile phone distraction on drivers' vision was further evident from optometry research by Maples et al. [23], who reported that mobile phone conversations tended to reduce the visual field, particularly by constricting the peripheral vision and awareness.

To the authors' knowledge, none of the prior studies on mobile phone distraction have examined the reaction times of distracted drivers across routine traffic events that occur directly in the central vision of a driver compared to events that occur within a driver's peripheral vision. Because vision- and brain-focused research has noted important peripheral vision effects, an investigation of the reaction times under these two conditions is useful for developing insights into the impairment of reaction times of

mobile phone distracted drivers and represents the unique contribution of this research.

Research objective

The objective of this study is to investigate the effects of mobile phone conversation on reaction times of drivers while they respond to traffic events in their peripheral and central vision. To accomplish this study, a group of distracted drivers were exposed to a number of traffic events using the CARRS-Q Advanced Driving Simulator. The remainder of the paper first describes the experimental details including a brief description of the driving simulator, experimental procedure, participants and data collection approach. The next section describes the dataset and statistical methods used for analysis, briefly describing the linear mixed modelling approach that accounts for repeated measures among individuals. The results of the analysis are then discussed, followed by overall conclusions of the research.

Method

Driving simulator

The experiment was conducted in the CARRS-Q Advanced Driving Simulator located at the Queensland University of Technology (QUT). This high fidelity simulator consisted of a complete car with working controls and instruments surrounded by three front-view projectors providing 180-degree high resolution field view to drivers. Wing mirrors and the rear view mirror were replaced by LCD monitors to simulate rear view mirror images. Road images and interactive traffic were updated on front-view projectors, wing mirrors and the rear view mirror at 60 Hz to provide a photorealistic virtual environment. The car used in this experiment was a complete Holden Commodore vehicle with an automatic transmission. The full-bodied car was rested on a six degree-of-freedom motion base that could move and twist in three dimensions to accurately reproduce motion cues for sustained acceleration, braking manoeuvres and interaction with varying road surfaces. The simulator used SCANeR™ studio software with eight computers linking vehicle dynamics with the virtual road traffic environment. The audio system of the car was linked with the simulator software so that it could accurately simulate surround sounds for engine and environment noise and sounds for other traffic interactions, e.g. a crash. Driving performance data like position, speed, acceleration and braking were recorded at rates up to 20 Hz.

Participants

The participants recruited for the study include thirty-two volunteers who were reimbursed upon completion of the study. They were recruited by disseminating recruitment flyers using university student email addresses or university

Facebook portals and posting recruitment flyers in a few key university locations, e.g. the library and canteen. In order to qualify as a participant they had to fulfil a number of requirements, including:

- be aged between 18 and 26 years;
- hold either a provisional or open Australian issued driver's licence;
- not had a history of motion sickness and epilepsy and;
- not be pregnant.

All data not collected in the simulator were self-reported.

The mean age of the participants was 21.47 (± 1.99) years and they were split evenly by gender; consisting of sixteen males and sixteen females. The mean ages for male and female were, respectively, 21.8 (± 1.80) and 21.1 (± 2.19) years. The average driving experience was 4.2 (± 1.89) years; about 44% drove less than ten thousand kilometres; about 47% drove about ten to twenty thousand kilometres; and the remainder drove more than twenty thousand kilometres in a typical year. About 34% of the participants held provisional licences and the rest had open (non-restricted) licences. Note that a provisional licence in Queensland, Australia is issued to a newly licenced driver for a duration of up to three years before they receive an open licence. The average driving experience of provisional and open licence holders were, respectively, 2.64 (± 0.75) and 5.01 (± 1.79) years. All of the participants had prior experience using mobile phones while driving for any purpose including talking or texting; 34% of the participants used mobile phones at least one time per day; 47% of the sample used a mobile phone one or two times in a week; and the remaining 19% used mobile phones while driving one or two times per month.

Experimental setup

The designed driving route in the CARRS-Q Advanced Driving Simulator contained simulated routes on both urban and rural areas. The simulated route was about seven kilometres long and included a detailed simulation of the Brisbane CBD with a great deal of accuracy, and a hypothetical suburban area which was created to meet the purpose of this research. The speed limit in the CBD was mostly 40 kph, whereas the speed limit in sub-urban areas varied between 50 and 60 kph. The simulated route was programmed to incorporate various 'traffic events' including a leading car that brakes suddenly, a pedestrian on a footpath that enters a zebra crossing, an overtaking scenario, gap acceptance manoeuvres at a number of intersections, and a car that drifts towards the driven car from the opposite direction. Three route starting points were designed to reduce learning effects and allow driving under the three different phone conditions, i.e. baseline, hands-

free and handheld. All three routes had the same geometry and road layout but the locations of traffic events were randomised across the routes. To examine the reaction times of distracted drivers to traffic events in their central and peripheral vision, two specific traffic events were included and analysed in this paper.

The first event occurred within a drivers' central vision, in which a driver needed to respond to a leading car that braked suddenly. This event occurred on a two lane road with one lane in each direction, separated by a broken centre line and the speed limit of 60 kph. The event was scripted such that the lead car maintained the same speed of the driven car by keeping a constant separation distance of about 36m. After travelling about 400m at the same speed, the lead car applied brakes; turning on the rear brake lights. The reaction time of a driver was measured as the time taken to press the brake pedal upon activation of the rear brake light of the lead car at the onset of braking. Maintaining speed behind the lead car did not require constant accelerator pedal pressure and hence the reaction time was deduced from the brake pedal and not the lifting of the accelerator pedal.

The second traffic event involved the peripheral vision of drivers, whereby a driver needed to respond to a pedestrian on a footpath who crossed the road at a zebra crossing. This event took place on a four-lane road with two lanes in each direction separated by a continuous centre line. The event took place within the CBD, where the speed limit was 40 kph. Although there were two lanes in each direction, the curb lane was mostly filled with parked vehicles, leaving the median lane available for driving. The event was scripted so that a pedestrian started to move from a footpath towards the zebra crossing when the driven car was about 10 seconds away from the zebra crossing. Since the zebra crossing in all three driving routes was placed mid-block after an intersection, drivers were accelerating to reach the posted speed limit after a recent turn at the prior intersection. Hence releasing the accelerator pedal in this event represented the initial reaction after detecting a pedestrian attempting to cross. As such, the reaction time was measured as time taken to release the accelerator pedal after the pedestrian that started to cross the road was perceived by the participant.

Mobile phone task

The mobile phone used in this study was a Nokia 500 phone which had dimensions of 111.3 x 53.8 x 14.1mm. For hands-free conversation, the drivers used a Plantronics Voyager PRO HD Bluetooth Headset connected with the phone through Bluetooth technology, which provided HD streaming audio wirelessly without interruption.

The phone conversation was cognitive in nature. Conversation dialogues were modified from Burns et al.

[15] for this study. Dialogues required the participant to provide an appropriate response after hearing a complete question, solving a verbal puzzle, or solving a simple arithmetic problem. An example question requiring a response was ‘Jack left a dinner in his microwave for Jim to heat up when he returned home. Who was the dinner for?’ A verbal puzzle example was ‘Felix is darker than Alex. Who is lighter of the two?’ An example arithmetic question was ‘If three wine bottles cost 93 dollars, what is the cost of one wine bottle?’ These types of questions required simultaneous storage and processing of information and thus distracted drivers by increasing their cognitive load.

Participant testing protocol

Prior to the experiment, participants were greeted by a 21 year old female host who gave all instructions and engaged in all remaining interactions with participants including the mobile phone conversations. An informed consent was first completed by each participant. The participants were then briefed about the project and completed a questionnaire that required about 20-25 minutes. The questionnaire items included driver demographics, driving history, general mobile phone usage history, usage of mobile phones while driving, and driver behaviour related to aggressiveness and sensation seeking. The participants were then briefed about the nature of phone conversations and how to use the mobile phone apparatus during the experiment. The host and participant then practiced several conversation dialogues using the hands-free device and handheld phone.

Participants were required to drive in three phone conditions: a baseline condition (without any phone conversation), and hands-free and handheld phone conditions. The driving conditions were counterbalanced across participants to control for carry-over effects. Before inviting a participant to step into the simulator, they were briefed about the driving simulator controls and instruments. Participants were instructed to drive as they normally would. Instructions were given to obey the posted speed limits and follow the directional signs towards the airport - thus participants had a navigational task. Before participating in the experimental drive, each participant performed a practice drive of five to six minutes to become familiar with the driving simulator. Participants encountered various traffic events including traffic lights, stop-sign intersections, overtaking scenarios, and gap acceptance manoeuvres during the familiarisation drive.

For experimental drives in the hands-free and handheld phone conditions, the experimenter called the participant before the start of the drive and there was a single continuous call until the end of the drive. The participants talked through a Bluetooth headset in the hands-free condition and were required to hold the phone to their ear for the duration of the conversation in the handheld condition. The host engaged in the phone conversation

was seated in a room away from the driving simulator and hence was neither able to observe a participant’s driving, nor receive any clues regarding route progress. When a participant reached the route starting point, after a closed loop drive of about seven kilometres through the Brisbane CBD and suburban areas, the scenario automatically ended. After each of the experimental drives, i.e. baseline, hands-free and handheld, participants completed a driving activity load index questionnaire while seated in the simulator vehicle. Participants took brief breaks while remaining in the vehicle between each experimental drive while the scenarios were loaded onto the simulator display system.

Data and analysis

Dataset for analysis

Reaction times were calculated for each participant during the two traffic events described previously - a lead vehicle braking suddenly and a pedestrian entering a zebra crossing from a footpath. Reaction times were measured for each participant across each of the three phone conditions, i.e. baseline, hands-free and handheld. Reaction times were compared across phone conditions and other explanatory variables such as driver age, gender and licence type. Driver age variable had three categories including age-group 1 (18-20 years), age-group 2 (21-22 years), and age-group 3 (23-26 years). Driver licence type had two categories, a provisional holder and an open licence holder. In addition, the approaching speed of drivers in these two traffic events was also collected and tested across phone conditions to investigate whether there is any correlation between speed selection and phone condition on influencing reaction times. An approaching speed was measured as the driven car’s speed at the time of activation of the simulated traffic event, e.g. at the moment when the lead car braked.

There was one observation where a participant selected a wrong lane to follow the lead car that braked suddenly and thus was discarded; forming a total of 95 observations for this event. There were seven occasions when drivers did not stop for pedestrians at the zebra crossing, including one in a baseline condition, four in the hands-free condition and two in the handheld condition. There were three other observations where drivers’ responses from the accelerator pedal were missing and hence reaction times were not possible to extract. These observations were discarded from the analysis of reaction times for this traffic event. In total there were 85 observations for 32 drivers representing an unbalanced panel data with a minimum of two and a maximum of three observations per driver.

Statistical analysis

Mean reaction times of individuals were computed for each traffic event across the three phone conditions, and compared using a repeated measures ANOVA and t-tests.

A repeated measures ANOVA in the form of a Linear Mixed Model was tested across phone conditions and other explanatory variables like driver age, gender and licence type to examine their effects and interactions in differentiating reaction times to a particular traffic event.

Since the dataset of this study had unbalanced repeated measurements, a repeated measures ANOVA in the form of a Linear Mixed Model was applied [24]. The Linear Mixed Model is superior to typical repeated measures techniques because it does not discard all results on any driver with a single missing measurement; rather it allows other data on drivers to be used as long as the missing data meets the missing-at-random definition. The Linear Mixed Model is capable of analysing variations between and within subjects of correlated data, where the correlation is a result of repeated observations of the same driver at multiple points in time.

Suppose $Y = (Y_{i1}, Y_{i2}, \dots, Y_{ik})'$ be the $k_i \times 1$ vector of reaction times in responding to a traffic event for driver i ($i = 1, 2, \dots, n$) at driving route k . The general Linear Mixed Model for longitudinal data is

$$Y_i = X_i\beta + Z_i\gamma_i + \varepsilon_i \quad (1)$$

where X_i is a $k_i \times p$ model matrix for the fixed effects for observations in driver i , β is the $p \times 1$ vector of fixed-effect coefficients, Z_i is the $k_i \times q$ model matrix for the random effects for observations in driver i , γ_i is the $q \times 1$ vector of random-effect coefficients, and ε_i is the $k_i \times 1$ vector of errors for observations in driver i . Random coefficient vector γ_i is assumed to be distributed as $\gamma_i \sim Nq(0, \psi)$, where ψ is a $q \times q$ covariance matrix for the random effects. Similarly, ε_i is assumed to be distributed as $\varepsilon_i \sim N_{k_i}(0, \sigma^2\Lambda_i)$, where $\sigma^2\Lambda_i$ is the $k_i \times k_i$ covariance matrix for the errors in driver i . The covariance matrix structure of the error term allows accommodating various forms of correlation originated from the repeated measures design. A compound symmetry structure that has constant variance and constant covariance was applied in this study. The general Linear Mixed Model in equation (1) is subject-specific and

hence it can have varying numbers of observations among subjects. A Mixed Model with fixed-effect regressors only, as is the case here, provides an analysis of variances for an unbalanced repeated measures dataset without losing information due to a missing measurement on any subject.

Results

The results discussed here refer to the reaction times of drivers to an event in the central vision and the reaction times of drivers to an event in the peripheral vision.

Reaction times to an event in the central vision

Table 1 shows the reaction times of drivers responding to a traffic event that occurred in their central vision (a lead car braking suddenly) as a function of phone condition and gender.

The reaction time differences in milliseconds were not statistically significant ($F_{2, 61.74} = 0.47$, p -value = 0.63) across phone conditions as estimated by the Linear Mixed Model. In general, the reaction time was about 44 ms (3.75%) higher when a participant was engaged in a hands-free phone conversation compared to baseline and the difference between reaction times of the handheld phone condition compared to baseline was -23 ms (-1.94%). None of the other explanatory variables like driver age, gender, and licence type was significant in explaining the variation of reaction times of drivers to the central event of a lead car braking.

Since participants may approach traffic events at different speeds, as evidenced by prior research [e.g., 8] that has shown reductions in speed selection while distracted, drivers at reduced speeds may have quicker reaction times. Drivers' approaching speeds to a lead car were statistically significant across phone conditions at 10% significance level ($F_{2, 61.05} = 2.48$, p -value = 0.09). The mean approaching speed in the baseline condition was 55 (± 8.1) kph, while the approaching speeds in the hands-free and handheld condition were, respectively, 52.6 (± 8.5) and 51.7 (± 8.4) kph. A lower speed selection on

Table 1. Reaction times to a traffic event that happened directly in line of sight of a driver: a lead vehicle suddenly braking

Participants	Statistic	Phone condition			% increase from baseline	
		Baseline	Hands-free	Handheld	Hands-free	Handheld
Reaction time in milliseconds (ms)						
All	Mean	1182	1226	1159	3.75	-1.94
	St. Dev	188	412	295		
Male	Mean	1197	1287	1181	7.58	-1.30
	St. Dev	174	553	352		
Female	Mean	1167	1165	1137	-0.09	-2.50
	St. Dev	208	192	233		

distracted conditions might have counteracted the effects of distraction on reaction times behind a lead car as observed in Table 1.

To test the effect of speed selection on reaction times, the approaching speed variable was included in the Linear Mixed Model after categorising into two categories, a low approaching speed group whose speed was less than or equal to 50 kph and a high approaching speed group whose speed was more than 50 kph at the time of lead car braked. While the effect of speed on reaction times was significant ($F_{1, 88.59} = 4.60, p\text{-value} = 0.04$), the interaction between speed and phone condition was not significant in explaining reaction times ($F_{2, 78.88} = 0.34, p\text{-value} = 0.71$). The mean reaction time for drivers with a low approaching speed was 1,095 milliseconds, while the reaction time for drivers with a high approaching speed was 1,239 milliseconds (Figure 1).

Reaction times to an event in the peripheral vision

Table 2 shows the reaction times of drivers when they responded to a traffic event occurring in their peripheral vision (pedestrian entered a zebra crossing from footpath) by phone condition and gender. Results are also graphically presented in Figure 2.

Reaction time differences in milliseconds were statistically significant across phone conditions ($F_{2, 54.29} = 10.15, p\text{-value} < 0.001$). In general the reaction times were about 55.2% ($t = 2.77, p\text{-value} = 0.007$) and 56.4% ($t = 3.13, p\text{-value} = 0.003$) higher when drivers were, respectively, distracted by a hands-free and handheld phone conversation compared to the baseline condition. The reaction time difference was not significant ($t = 0.05, p\text{-value} = 0.957$) between the hands-free and handheld phone conditions.

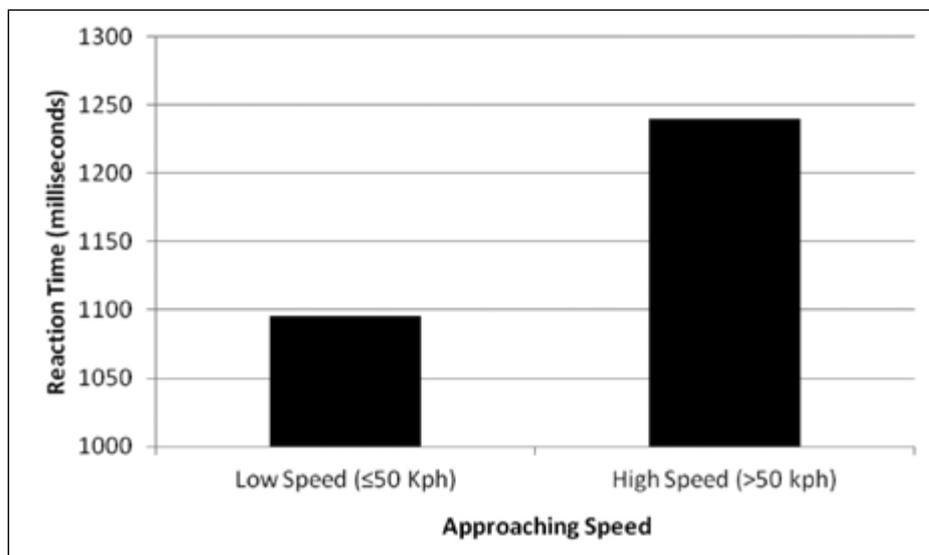


Figure 1. Reaction times across approaching speeds to an event where a lead vehicle braked

Table 2. Reactions times to an event originating in a drivers’ peripheral vision: a pedestrian entering a zebra crossing from a footpath

Participants	Statistic	Phone condition			% increase from baseline	
		Baseline	Hands-free	Handheld	Hands-free	Handheld
Reaction time in milliseconds (ms)						
All	Mean	1873	2907	2929	55.20	56.38
	St. Dev	1138	1669	1399		
Male	Mean	1917	2800	3039	46.06	58.53
	St. Dev	1188	1620	1574		
Female	Mean	1830	3014	2811	64.70	53.60
	St. Dev	1125	1771	1236		

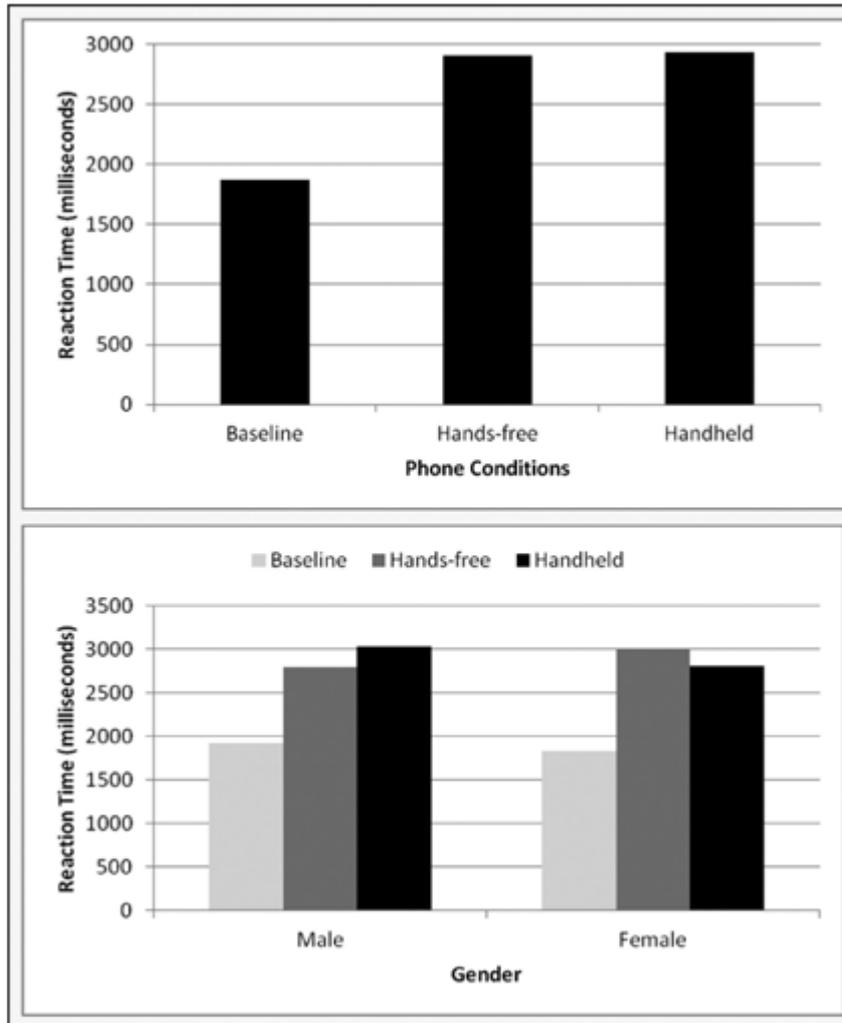


Figure 2. Reaction time across phone conditions and gender for an event in the peripheral vision of drivers

An interaction between phone condition and gender was not significant ($F_{2, 47.29} = 0.92$, p -value = 0.41), and hence similar deteriorations of reaction time were observed for distracted males and females. For males, the reaction times were 46.1% higher ($t = 1.68$, p -value = 0.10) in the hands-free and 58.5% higher ($t = 2.18$, p -value = 0.04) in the handheld compared to the baseline condition. For females, the reaction time difference was higher by 64.7% ($t = 2.17$, p -value = 0.039) in the hands-free and 53.6% ($t = 2.20$, p -value = 0.037) in the handheld compared to the baseline condition. There was no significant difference between reaction times in the hands-free and handheld phone condition both for males ($t = 0.40$, p -value = 0.70) and females ($t = 0.35$, p -value = 0.75).

Reaction times were statistically different at 10% significance level across licence types ($F_{1, 30.58} = 3.45$, p -value = 0.073) but not significant when an interaction between phone condition and licence type was considered ($F_{2, 52.1} = 1.45$, p -value = 0.245). The mean reaction time for drivers with an open licence was 2,275 milliseconds,

while the reaction time for drivers with a provisional licence was 3,051 milliseconds. Figure 3 shows the reaction time across phone conditions and licence types when drivers responded to a traffic event in their peripheral vision. For drivers with an open licence, the reaction times were about 43.7% ($t = 1.78$, p -value = 0.08) and 39.2% ($t = 1.77$, p -value = 0.09) higher, compared to the baseline condition, when drivers were distracted by a hands-free and hand-held phone conversation respectively. The reaction times for provisional licence holders were higher by 72.5% ($t = 2.17$, p -value = 0.04) in the hands-free and 80.7% ($t = 2.88$, p -value = 0.01) in the handheld conversation compared to the baseline condition. In summary, the deterioration of reaction times due to a phone conversation was almost double for provisional than open licence holders. Reaction time differences between hands-free and handheld condition were not significant both for open ($t = 0.16$, p -value = 0.87) and provisional ($t = 0.25$, p -value = 0.81) licence holders.

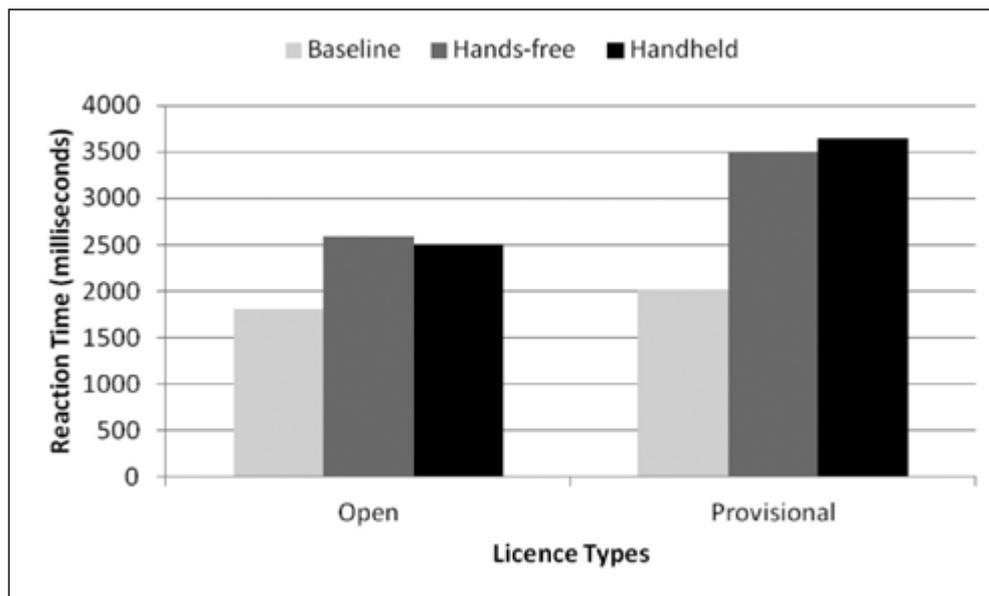


Figure 3. Reaction time across phone conditions and licence types for an event in the peripheral vision of drivers

Drivers' approaching speeds to a pedestrian crossing were not statistically significant across phone conditions ($F_{2, 55.61} = 0.26$, p -value = 0.77). The mean approaching speed in the baseline condition was 35.1 (± 4.5) kph, while the approaching speeds in the hands-free and handheld condition were, respectively, 34.8 (± 5.4) and 35.2 (± 5.6) kph.

Discussions and conclusion

Much research has established that reaction times increase when mobile phones are used whilst driving. Research has also revealed that mobile phone use constricts the field of view of drivers. This research set out to examine and quantify the extent to which reaction times differ when coping with traffic events in a driver's central vision compared to an event in the peripheral vision.

It was confirmed in this study that reaction times are slowed when drivers are distracted. Importantly, reaction times were not statistically different in the baseline compared to hands free and hand held conditions of young drivers in this study when confronted with events in their central vision - suggesting that both perceptions and reactions were not affected when the phone was used. In contrast, an event originating in a driver's periphery was found to be quite problematic for drivers to detect and thus raises some significant safety concerns.

Speed selection appears to play a role in compensating for the distracting effects of phone use for the traffic event in the central but not peripheral vision. Approaching speeds were different across phone conditions in an event occurring in the central vision, where drivers were slower when distracted. This effect suggests risk compensation, an

affect that has also been noted in other research [e.g., 9, 16], where drivers compensate for their increased perceived risk of talking on the phone by lowering their driving speed. The approaching speed when confronted with an event in the periphery, however, was slightly lower but not statistically significant compared to the baseline condition. Two driver responses might explain this finding. First, drivers were on an accelerating phase to catch up the speed limit after a prior turn at this point in the simulation, and second, the magnitude of the risk compensation may be comparatively less when drivers are confronted by a peripheral event or when drivers are not confronted by any direct traffic interaction like the case of lead vehicle in the central vision.

The role of a provisional licence played an important role and is associated with greater risk. Previous research has reported that the combined effect of being inexperienced and distracted is particularly risky in case of a critical driving situation like responding to an amber light at signalised intersections [25]. Clearly, driving experience also seems to influence reaction times, particularly to a traffic event in the peripheral vision. It is also quite possible that less experienced drivers are less skilled at scanning the field of view and this effect is higher when they are distracted.

Many critical events originate in a driver's periphery, including vehicles, bicyclists and pedestrians emerging from side streets. A reduction in the ability to detect these events while distracted presents a significant safety concern that must be addressed. There were seven occasions when drivers did not stop for pedestrians at zebra crossing, including one in the baseline condition, four in the hands-free condition, and two in the handheld condition - six out of seven cases were when drivers were distracted. In reality these conditions may have resulted in a crash and potential injury.

Distracted driving as a result of mobile phone conversations impaired the reaction times of young drivers to a traffic event in their peripheral but not central vision. It is worth noting that a lead vehicle braking in the central vision and a pedestrian entering a zebra crossing from the footpath in the peripheral vision have different object size and event dynamics, which hinders a quantitative comparison across these events. Additional simulator studies with controlled object size and dynamics would be helpful to develop further insights into the problem, as well as to identify ways to mitigate the effects of distraction particularly in encountering traffic events in a driver's periphery. Furthermore, reaction times for the peripheral event in this study were measured from the time of use of accelerator pedals, mainly because zebra crossings were located at mid-blocks after intersections. This experimental set up required drivers to accelerate to reach the speed limit after a recent turn at the prior intersection. Realising the fact that a brake-related action is a more indicative response to a hazardous event, an additional simulator study could be designed where a series of zebra crossings are placed along a straight segment of road and distracted driver responses to pedestrians entering random zebra crossings are measured.

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Safety performance functions for traffic signals: phasing and geometry

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Abstract

A significant proportion of urban crashes, especially serious and fatal crashes, occur at traffic signals. Many of the black-spots in both Australia and New Zealand cities occur at high volume and/or high speed traffic signals. Given this, crash reduction studies often focus on the major signalised intersections. However, there is limited information that links the phasing configuration, degree of saturation and overall cycle time to crashes. While a number of analysis tools are available for assessing the efficiency of intersections, there are very few tools that can assist engineers in assessing the safety effects of intersection upgrades and new intersections. Safety performance functions have been developed to help quantify the safety impact of various traffic signal phasing configurations and level of intersection congestion at low and high-speed traffic signals in New Zealand and Australia.

Data from 238 signalised intersection sites in Auckland, Wellington, Christchurch, Hamilton, Dunedin and Melbourne was used to develop crash prediction models for key crash-causing movements at traffic signals. Different variables (road features) effect each crash type. The models indicate that the safety of intersections can be improved by longer cycle times and longer lost inter-green times, especially all-red time, using fully protected right turns and by extending the length of right turn bays. The exception is at intersections with lots of pedestrians where shorter cycle times are preferred as pedestrian crashes increase with longer wait times. A number of factors have a negative impact on safety including, free left turns, more approach lanes, intersection arms operating near or over capacity in peak periods and higher speed limits.

Keywords:

crash prediction models, generalised linear models, traffic signal layout and phasing, pedestrian safety and safety performance functions

Introduction

The majority of urban crash black-spots (or hot-spots) occur at major signalised intersections. While crash reduction studies often focus on such intersections there is

limited information that links the phasing configuration, degree of saturation of each movement and overall cycle time to crashes. Most changes to the signal phasing, other than right turning phases, occur for efficiency reasons. Safety improvements often focus on other factors like conspicuousness of the signals, the amount of inter-green time and approach skid resistance.

Many traffic signal and road safety engineers/professionals have anecdotal experience that signal phasing and traffic congestion (and the resulting driver frustration) has an effect on road safety. However this effect has not been well quantified and there is only limited research on what the safety effects are, both good and bad, of changes to signal phasing and congestion relief. The result is that many changes to traffic signal phasing are being made without a good understanding of the safety implications of these changes.

While there is some international research on this topic, including before and after studies of the safety of various intersection features, there is a lot of variety in the layouts of traffic signals between different countries, and in the case of large countries, like the USA, from State to State and even city to city. This does mean that such studies are not directly transferable to New Zealand and Australia, which typically have similar traffic signal lay-outs, with some local variations. The overseas research does however help in identifying the key features that impact safety at traffic signals, and should be included in the models.

Some of the earliest accident prediction models (or safety performance functions) for traffic signals were produced by TRL in the United Kingdom. Hall [1] analysed four years of crash data from 1979 to 1982 at 177 four-leg urban intersections on 30 mile/h roads throughout the United Kingdom. The report divided intersections into eight groups based on the presence (or lack thereof) of Urban Traffic Control, pedestrian stages, and right turn stages (or more or less than two stages). Hall derived significant crash prediction models for total crashes, vehicles only, pedestrian crashes and 11 specific types of crashes. The best fitting models (and the simplest) were functions of all 12 vehicular flows into the intersection (three movements on each leg) and the total vehicular and pedestrian flows.

Hall further tested geometric variables at the intersections and found significant models correlating crashes with approach width, number of approach lanes, approach horizontal curvature, sight distance and gradient on the approach, horizontal displacement across the intersection (when approaches are not exactly opposite one another), the angle of intersecting roadways, yellow box “no stopping” markings, the position of the secondary signal and the presence of a pedestrian refuge island. Operational variables that had a significant correlation with crashes included the sequencing of the right turn (leading vs. lagging), the number of stages, the length of the cycle time, the degree of saturation, the inter-green time and the presence of a pedestrian stage.

In the United States, Poch and Mannering [6] carried out similar research on 63 intersections in Bellevue, Washington, US where intersection improvements had been carried out between 1987 and 1993; not all of these intersections were signalised. Poch and Mannering used a negative binomial model to correlate crashes with intersection variables. Significant variables at the signalised intersections included the number of phases (e.g. whether left turns (or right turns in New Zealand) were given their own phase), protection of left (right in New Zealand) turns, restricted sight distance, approach gradient, horizontal curvature and the approach speed limit.

Interestingly, Poch and Mannering found an increase in the crash rate when the approach had two or more lanes and a shared left-through lane (right and through lane in New Zealand) because “(1) Left-turning vehicles that must stop and wait for a gap to complete the manoeuvre cause a high potential for rear-end crashes as through vehicles approach in the same lane at prevailing speed; and (2) stopped left-turning vehicles that face stopped left-turning vehicles in the opposing approach must overcome the sight restriction to the opposing through vehicles to successfully complete the manoeuvre.” This arrangement (or rather, combined right-through lanes) is employed in a number of locations in New Zealand, normally due to space restrictions at the intersection.

Kumara and Chin [3] evaluated signalised intersections in Singapore. They used a modified Poisson under-reporting model on a sample size of 104 three-legged intersections with nine years of crash data to identify crash causal factors and take into account the traditional under-reporting of crashes to the police. Kumara and Chin specifically highlighted unprotected left-turn slip roads, the number of signal phases per cycle, the use of permissive right turning phases, and restricted sight distances less than 100m as variables that increase crash rates, while right turn channelisation, left turning acceleration lanes, obvious camera surveillance, anti-pedestrian median railing, obtuse intersection angles and approach gradients greater than 5% reduce crash rates. The report expressed some surprise at

the reduction in crashes from uphill approaches, noting that “an uphill grade into an intersection may lead to reduced vehicle speeds, while obtuse angles require reduced turning speeds in order to navigate right turns.”

Mitra et al. [5] also looked into crashes at four-legged signalised intersections in Singapore, specifically at side-impact and rear-end crashes, which account for 84% of all crashes in Singapore, at such intersections. This research involved the development of zero-inflated probability models, which account for data from intersections during intervals where there are no recorded crashes. This research highlighted that closely adjacent intersections and bus bays will decrease the rate of side-impact crashes, whereas greater sight distance, the presence of pedestrian refuge islands and higher approach speeds increase the rate. Rear-end crashes appear to decrease with adaptive signal control and increase with camera surveillance. Crashes of all kinds increased with the presence of uncontrolled channelised left turns, wider medians, higher approach volumes and an increase in the number of signal phases.

At signalised crossroads, Roozenburg and Turner [7] found that all crash types decreased per vehicle with increasing conflicting flows except rear-end crashes, which increased with increased traffic volumes through an intersection. Data on three-leg intersections showed similar trends for rear-end, loss-of-control, and catchall “others” crashes but there were conflicting conclusions for right-turn-against and crossing crashes. These models were further refined with the addition of non-volume variables to help quantify right turn phasing impacts: number of opposing through lanes, right turn bay offset, intersection depth, right-turn signal phasing (e.g. filtered turns or protected turns) and visibility to opposing traffic. However, only the number of opposing through lanes was deemed to improve the above models. The small data set may have limited some of the variables’ influence.

The objective of this research was to quantify the effect that signal phasing has on various crash types at traffic signals in New Zealand and Australia, taking into account the speed limits (and where available, operating speeds), the intersection geometry and the surrounding land-use, be it industrial, commercial (e.g. shopping) or residential, or a combination. Factors such as horizontal and vertical approach alignment have also been factored into the evaluation, along with the duration and configuration of the lost time between signal phasing. Data has been collected in several cities, in order to pick-up the safety impacts of variations in traffic signal set-up.

Modelling methodology

Safety Performance Functions (SPFs) are mathematical models that relate crashes to road user volumes and other road layout and operational features. SPFs are cross-sectional regression models. With crashes being discrete

events, and typically following a Poisson or negative binomial distribution, traditional regression analysis methods such as linear regression are not suitable. The models used in crash prediction are developed using generalised linear modelling methods.

Generalised linear models were first introduced to road crash studies by Maycock and Hall [4], and extensively developed in Hauer et al. [2]. These models were further developed and fitted using crash data and traffic counts in the New Zealand context for motor-vehicle-only crashes by Turner [8]. While more advanced modelling methods have been examined in the literature, generalised linear models, with a negative binomial error structure, continue to be preferred by many researchers as in most studies these other modelling methods do not result in a significant improvement in the model fit.

The aim of this modelling exercise is to develop relationships between the mean number of crashes (as the response variable), and traffic flows, as well as non-flow predictor variables. Typically the models take the multiplicative form,

$$A = b_0 x_1^{b_1} \dots x_i^{b_i} e^{b_{i+1} x_{i+1}} \dots e^{b_n x_n}$$

where A is the mean annual crashes, the x_1 to x_i are measurement variables, such as average daily flows of vehicles, and the x_{i+1} to x_n are categorical variables, recording the presence, for example, of a cycle installation, and the b_1, \dots, b_n are the model coefficients.

Software has been developed in Minitab in order to fit such models (i.e. to estimate the model coefficients). The popular Bayesian Information Criterion (BIC) has been used as the preferred criterion to decide when the addition of a new variable is worthwhile.

Goodness of fit testing of all models (using the scaled deviance) has also been undertaken by using software that has been written in the form of Minitab macros. This method is based on the work by Wood [11], which takes into account the low mean value problem. The low mean value problem can influence the accuracy of the scale deviance statistic and often occurs when the crash data is disaggregated into various crash types and by time of day. A detailed description of the modelling methodology adopted is given in Wood and Turner [12].

Like all analysis methods there are a number of limitations to the models including; the quality of the data collected for each intersection (given the large sample size there are bound to be errors in the data collected), correlation between predictor variables (this has been minimised) and systematic endogeneity bias (where some features might be introduced only at high crash sites – this is unlikely to be a factor in most if not all predictor variables).

Sample selection and data collection

Signalised intersection sites were selected primarily from a desktop assessment of road maps and aerials, in the six cities. Only three-arm and four-arm traffic signals were included in the sample set, with all arms being two-way and with few turning restrictions. All intersections were on the cities SCATS signal control system (so SCATS signal phasing and traffic count data could be collected) and a significant proportion were on a coordinate traffic signal route. Both low and high speed signals were included in the sample set.

It was recognised that some of the intersections initially selected during the desktop assessment may have undergone significant changes over the five year (crash) study period (2004-2008). Major changes can have an impact on the annual crash frequencies at intersections and introduce error into the modelling. None of the cities had a comprehensive database of changes that had occurred at their traffic signals during this time period. In some cases it was not possible even to confirm the date the traffic signals were installed. In all cities we did have access to experienced and knowledgeable traffic signal engineers that were able to identify those traffic signals that had had significant changes and improvements in this period. The following changes were deemed to be significant; changes to intersection geometry (e.g. addition of traffic lanes), changes to signal phasing (e.g. addition of protected turning phases) and addition of signal aspects or mast arms.

Table 1 shows the number of intersections and approaches selected in each city and the number of intersections that were excluded because of significant changes over the five year study period. Only 31 sites were classified as high speed (13% of the sample). These are intersections where at least one of the intersecting roads has a speed limit equal or greater than 80kph. The majority of the traffic signals had four arms (181).

Data was collected on a wide range of physical and operational characteristics of the signalised intersections. The data was collected for each individual approach of the selected signalised intersection sites. Figure 1 presents a summary of the different categories of data that was collected at each site and the source of the data.

A large number of geometric variables were included in the data set, including facilities for pedestrians, cyclists, buses, motor-vehicles and parking. Key variables included intersection width and depth, number of approach lanes, presence of pedestrian crossings, cycle storage and approach lanes, bus bays and parking in the vicinity of the intersection, offset of right turn bays and distance to the upstream intersection.

Table 1. Selected traffic signals by location

Location	Initial number of selected intersections	Exclusions	Final number of selected intersections	Number of approaches at selected intersections
Auckland	127	38	89	324
Christchurch	66	13	53	205
Dunedin	14	3	11	43
Hamilton	27	10	17	66
Melbourne	69	11	58	214
Wellington	44	34	10	37
	Total		238	889

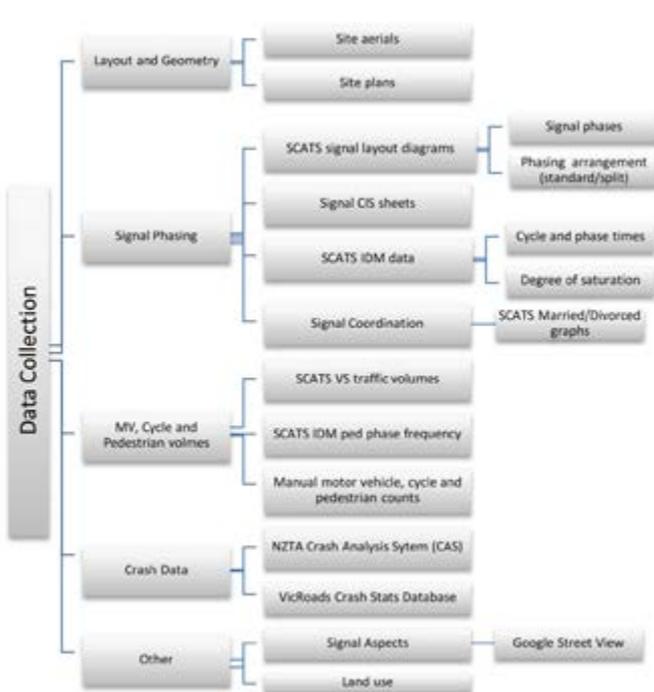


Figure 1. Categories of variables used in the study

Traffic signal layout variables include height of signal poles, presence of mast arms, number of signal aspect per approach and the layout of the signal aspects. Signal operational variables include cycle time, standard and split phasing, type of right turn phase (filtered, partially and fully protected) and signal coordination (i.e. whether linked with other signals).

Modelling results

Figure 2 presents the various categories of safety performance functions that have been developed in this study. Models were developed for the main crash types for motor-vehicle only and pedestrian versus vehicle crashes and for peak periods only. Appendix A shows the movement coding diagram used in New Zealand. Appendix B includes a description of each of the variables used in the models. It should be noted that the models show the

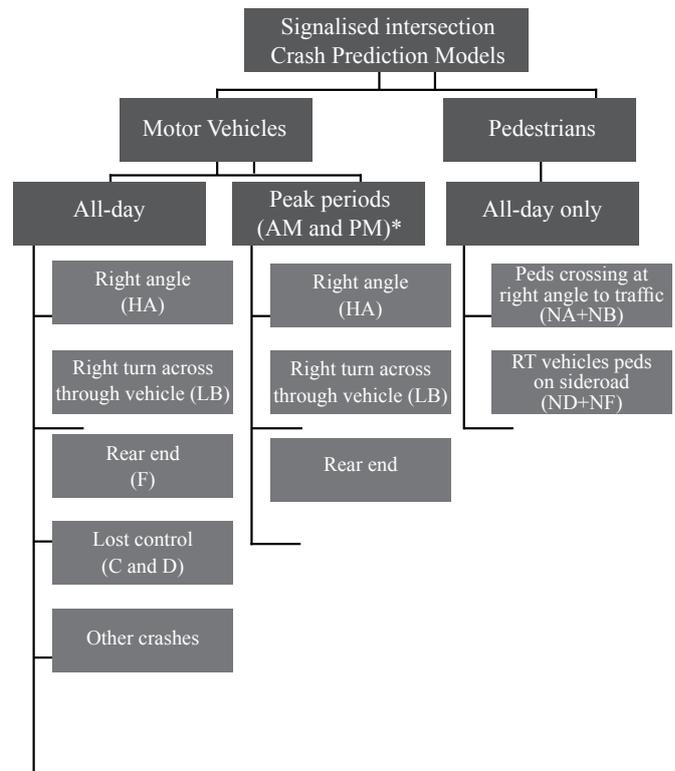


Figure 2. Safety Performance Function Categories

association between each variable and crashes and this does not necessarily mean causation. When key variables are missing or where there is correlation between variables the relationship between a variable and crashes may be unclear, and represent a number of factors. While this is not generally the case here, we suggest readers are cautious in interpreting the results of the modelling.

Models for cycle versus motor-vehicle crashes were not developed as there were insufficient intersections where cycle counts were available. Turner et al. [9] does look at bicycle crashes at traffic signals, using data from Christchurch and Adelaide, where cycle counts are readily available.

Table 2. Right angle crashes models (Type HA)

Crash Movement	Final Model	B0 Coefficient	Model Parameters	Error Structure	P-Value
All-cities model: flow-only model	$A_{HA} = B_0 \times q_2^{0.29} \times (q_5+q_{11})^{0.3}$	$B_0 = 1.77E-03$			
All-cities model: all important variables	$A_{HA} = B_0 \times q_2^{0.311} \times (q_5+q_{11})^{0.362} \times \exp(0.356 \times \text{Number of approaching lanes}) \times (\text{Intersection depth})^{0.602} \times (\text{Cycle time})^{-0.037} \times (\text{All-red time})^{-0.836} \times F_{\text{Split phasing}} \times F_{\text{Mast arm}} \times F_{\text{Coordinated}} \times F_{\text{Adv detector}} \times F_{\text{Shared turns}} \times F_{\text{Med island}}$	B0 (Auckland) 4.27E-05 B0 (Wellington) 2.08E-05 B0 (Christchurch) 8.69E-05 B0 (Hamilton) 1.13E-04 B0 (Dunedin) 1.54E-04 B0 (Melbourne) 4.11E-05	FSplit phasing 0.69 FMast arm 0.74 FCoordinated 1.31 FAdv detector 2.06 FShared turns 1.19 FMed island 0.67	Negative Binomial	0.021
Auckland and Melbourne model	$A_{HA(AKL,MEL)} = B_0 \times q_2^{0.455} \times (q_5+q_{11})^{0.47} \times \exp(0.397 \times \text{Number of approaching lanes}) \times (\text{Intersection depth})^{0.494} \times (\text{Cycle time})^{-0.286} \times (\text{All-red time})^{-1.321} \times F_{\text{Split phasing}} \times F_{\text{Mast arm}} \times F_{\text{Coordinated}} \times F_{\text{Adv detector}} \times F_{\text{Shared turns}} \times F_{\text{Med island}}$	$B_0 = 2.18E-05$	FSplit phasing 0.93 FMast arm 0.77 FCoordinated 0.85 FAdv detector 2.20 FShared turns 0.68 FMed island 0.57	Poisson	0.19
Peak period model	$A_{HA(Peak)} = B_0 \times q_2^{0.156} \times (q_5+q_{11})^{0.361} \times \exp(0.788 \times \text{Number of approaching lanes}) \times (\text{Intersection depth})^{1.237} \times (\text{Cycle time})^{-0.945} \times (\text{All-red time})^{-2.528} \times F_{\text{Split phasing}} \times F_{\text{Mast arm}} \times F_{\text{Coordinated}} \times F_{\text{Shared turns}} \times F_{\text{Med island}}$	$B_0 = 6.61E-05$	FSplit phasing 0.35 FMast arm 0.56 FCoordinated 1.49 FShared turns 2.06 FMed island 1.19		

Right angle crashes

Table 2 shows the models that were developed for right angle crashes (HA type). This crash type involves straight through vehicles on one approach (q2) colliding with a straight through vehicle on an approach to the left (q5) or right (q11) of the first approach (refer to Appendix A for coding conventions used in New Zealand crash data and coding description for each traffic movement). For this crash type a ‘flow-only’ model and full variable model was developed for all sites for all-day crashes. A separate model was also developed for the peak periods during the working week.

The magnitudes of the constant term (B0) for the different cities in this model points to a significant variation in the number of HA crashes between cities. This is also likely to be the primary cause of the large variation seen in model results and the resulting low goodness of fit. However, the model does indicate the factors that have a significant effect on safety. Both intersection traffic flow volumes are observed to have similar coefficients. Larger intersections - those having more approach lanes and larger intersection depths - also have more crashes. Split phasing and presence of a mast arm or raised median/central island on the approach are seen to reduce the number of crashes, while approaches having shared turns and traffic signals lying along a coordinated route generally tend to have more crashes. Surprisingly, approaches with an advance SCATS detector appear to have twice the number of crashes as compared to those where these detectors are not present.

Due to the similarities observed between Auckland and Melbourne within this crash group (with similar B0s), a separate model was developed specifically for these two (large) cities. This model had a Poisson error structure and a p-value of 0.19, which indicates that the model is

a satisfactory fit. Larger intersections have more crashes, although reduction in cycle time and all-red time has a greater positive effect on safety. Presence of split phasing, mast arms and raised medians reduces crashes, although the magnitude of reduction for split phasing is lower than that predicted by the first model. Presence of an advance SCATS detector is again observed to have a large negative effect on safety. However, in contrast to the model for all cities, presence of shared lanes and signal coordination is seen to result in a decrease in crashes for Auckland and Melbourne.

The models for peak periods show some differences in the importance of variables. Interestingly, the conflicting traffic flow from the left and right side of the main vehicle is significantly more important in the morning and evening peak periods as compared to the whole day. The effect of larger intersection size (more crashes), split phasing (fewer crashes) and shared turns (more crashes) is also seen to be more significant in the peaks. Presence of advance detectors is not seen to have an effect in this model.

Right turn against models

Table 3 shows the models that were developed for right turn against crashes (LB type). This crash type involves a vehicle turning right (q7) colliding with an opposing straight through vehicle (q2). This can occur at four different conflict points at a signalised crossroads. Flow only and full variable models were developed for all-day crashes and a model was developed for the peak periods.

The all-day model for right-turn-against crashes suggests that the right turning traffic volume is a more significant contributor in these crashes than the through traffic volume. Wider approaches (i.e. those having more lanes for through traffic) are more prone to these crashes. Extending the length of the right turning bay or lane results in fewer

Table 3. Right turn against models (Type LB)

Crash Movement	Final Model	B0 Coefficient	Model Parameters	Error Structure	P-Value
All-day model: flow-only	$A_{LB} = B_0 \times q_2^{0.13} \times q_7^{0.145}$	$B_0 = 5.12E-02$			
All-day model: all important variables	$A_{LB} = B_0 \times q_7^{0.155} \times (1 + \text{Length of RT bay or lane})^{-0.124} \times \exp(0.352 \times \text{Number of through lanes}) \times (\text{Degree of saturation})^{0.397} \times (\text{Cycle time})^{-0.683} \times F_{\text{Full RT Protection}} \times F_{\text{Shared RT}} \times F_{\text{Med island}} \times F_{\text{Cycle facilities}}$	B0 (Auckland) 3.83 B0 (Wellington) 4.10 B0 (Christchurch) 4.41 B0 (Hamilton) 2.27 B0 (Dunedin) 4.16 B0 (Melbourne) 3.95	FFull RT Protection 0.71 FShared RT 0.72 FMed island 1.22 FCycle facilities 1.35	Negative Binomial	0.041
Peak period model	$A_{LB(\text{Peak})} = B_0 \times q_7^{0.256} \times (1 + \text{Length of RT bay or lane})^{0.111} \times \exp(0.26 \times \text{Number of through lanes}) \times (\text{Degree of saturation})^{0.41} \times (\text{Cycle time})^{-0.034} \times F_{\text{Full RT Protection}} \times F_{\text{Shared RT}} \times F_{\text{Med island}}$	$B_0 = 5.82E-03$	FFull RT Protection 0.24 FShared RT 0.56 FMed island 1.84		

Table 4. Rear-end models (F Type)

Crash Movement	Final Model	B0 Coefficient	Model Parameters	Error Structure	P-Value
All-day model: flow-only	$A_{\text{Rear End}} = B_0 \times q_2^{0.89}$	$B_0 = 1.01E-04$			
Small intersections	$A_{\text{Rear end (small)}} = B_0 \times q^{0.447} \times (1 + \text{Length of right turn bay or lane})^{-0.209} \times (\text{Lost time})^{-3.424} \times F_{\text{Split Phasing}} \times F_{\text{Approach bus bay}} \times F_{\text{Cycle facilities}} \times F_{\text{FLT}}$	B0 (Auckland) 1.38E+00 B0 (Wellington) 6.58E-01 B0 (Christchurch) 4.34E+00 B0 (Hamilton) 1.36E+00 B0 (Dunedin) 7.95E+00 B0 (Melbourne) 1.25E+00	FSplit Phasing 5.256 FApproach bus bay 1.309 FCycle facilities 0.706 FFLT 1.585	Poisson	0.022
Medium intersections	$A_{\text{Rear end (medium)}} = B_0 \times q^{0.496} \times \exp(0.243 \times \text{Number of approaching lanes}) \times (\text{Lost time})^{-0.209} \times F_{\text{Cycle facilities}} \times F_{\text{Standard phasing}} \times F_{\text{FLT}} \times F_{\text{High speed}} \times F_{\text{Approach bus bay}} \times F_{\text{Commercial}}$	B0 (Auckland) 9.56E-04 B0 (Wellington) 1.41E-03 B0 (Christchurch) 1.12E-03 B0 (Hamilton) 9.29E-04 B0 (Dunedin) 3.06E-03 B0 (Melbourne) 1.16E-03	FCycle facilities 0.753 FStandard phasing 0.637 FFLT 1.442 FHigh speed 1.449 FApproach bus bay 0.908 FCommercial 0.900 FHigh speed 0.985	Negative Binomial	0.047
Large intersections	$A_{\text{Rear end (large)}} = B_0 \times q^{0.358} \times \exp(0.459 \times \text{Number of approaching lanes}) \times (1 + \text{Length of right turn bay or lane})^{1.142} \times (\text{Lost time})^{-1.739} \times F_{\text{High speed}} \times F_{\text{Standard phasing}} \times F_{\text{Cycle facilities}} \times F_{\text{FLT}} \times F_{\text{Commercial}}$	B0 (Auckland) 3.92E+00 B0 (Christchurch) 7.74E-01 B0 (Melbourne) 3.36E+00	FStandard phasing 1.053 FCycle facilities 1.257 FFLT 1.227 FCommercial 0.819	Poisson	NA
Peak period models	$A_{\text{Rear end (small, peaks)}} = 4.30E-03 \times q^{0.252} \times F_{\text{Split phasing}}$		Fsplit phasing = 2.33		
Peak period models	$A_{\text{Rear end (medium, peaks)}} = 7.89E-04 \times q^{0.457} \times \exp(0.277 \times \text{Number of approaching lanes}) \times F_{\text{High speed}} \times F_{\text{Standard phasing}} \times F_{\text{Cycle facilities}} \times F_{\text{Approach bus bay}} \times F_{\text{FLT}} \times F_{\text{Commercial}}$		FHigh speed = 1.630 FStandard phasing = 0.572 FCycle facilities = 0.754 FApproach bus bay = 0.692 FFLT = 1.604 FCommercial = 0.653		
Peak period models	$A_{\text{Rear end (large, peaks)}} = 6.42E-04 \times q^{1.181} \times \exp(0.465 \times \text{Number of approaching lanes}) \times (1 + \text{Length of right turn bay or lane})^{-1.478} \times F_{\text{High speed}} \times F_{\text{Standard phasing}} \times F_{\text{Cycle facilities}} \times F_{\text{FLT}} \times F_{\text{Commercial}}$		FHigh speed = 1.756 FStandard phasing = 1.257 FCycle facilities = 0.443 FFLT = 0.788 FCommercial = 0.925		

crashes. Degree of saturation is also observed to have a significant negative effect on safety for this crash type. As was the case with HA crashes, longer cycle times also result in a reduction in LB crashes. Fully protected right turn phasing, and shared right/through lanes improve safety, while presence of a raised median and cycle facilities results in higher crash rates.

The right turning traffic volume is observed to have a greater effect on crashes in the peaks as compared to the all-day period. Interestingly, longer right turning bays/lanes results in a slight increase in crashes. Longer cycle times still reduce crashes, although the effect is quite diminished. The effect of full right turn protection (fewer crashes), shared right/through lanes (fewer crashes) and presence of raised median or central island (more crashes) is more pronounced as compared to the all-day period.

Rear-end models

Table 4 shows the models developed for rear-end crashes (F Type). Models that utilised data from all selected intersections were initially developed for rear end crashes. However, a large degree of variation due to intersection size was observed in these model results. It was thus felt necessary to develop models based on the size of the signalised intersection. Intersections were split into three size categories, and crash prediction models were built for each. These categories are: small intersections (those having one or two approaching lanes and intersection depth of 25m or less), large intersections (those having three or more approaching lanes, and an intersection depth of 40m or greater) and medium intersections (those not lying in either of the other two categories). Table 5 shows the number of approaches that fall within each size category, along with the total number of rear end crashes.

Table 5. Number of approaches and crashes by intersection size classification

Intersection size	Number of approaches	Number of crashes
Small	201	36
Medium	611	184
Large	77	93

The all-day rear-end crash model for medium sized intersections shows a strong relationship between crashes and the total approach traffic volume. Intersections with more approach lanes also have increased crash numbers. Although lost time has a positive coefficient, this is likely

to be the result of variation within the sample set (the non city-covariate model showed a reduction in crashes with longer lost times). The model results also indicate that intersections that operate using a ‘standard’ phasing arrangement and approaches having cycle facilities, have fewer rear-end crashes. A high speed environment and presence of a free left turn for motor vehicles is seen to negatively affect safety. Presence of an approach bus bay within 100m upstream of the approach limit line and commercial land use environment also appears to lead to slight reductions in rear-end crashes. There was some variation in results at small and large intersections.

The total approach traffic volume during peak periods is observed to show a significant relationship with crashes for medium intersections, while the effect for smaller and larger intersections is less pronounced in comparison. The ‘standard’ phasing arrangement improves safety at small and medium sized intersections, but not at large intersections where split phasing is more common. The model coefficients also indicate that higher speeds on approaches are a more important factor during the peaks as compared to the all-day period, with more crashes occurring in high speed environments. In contrast to the results of the all-day model, the presence of free left turn lanes at larger intersections is shown to reduce rear-end crashes during peak periods.

Loss of control and other crashes

Table 6 shows the all-day loss of control (Type C and D) and a general model of all other crash types. This Table shows that that more loss of control crashes occur on intersection approaches that have higher volumes, wider approaches and are close to or over-saturated. Increasing

Table 6. Loss-of-control and ‘other’ crash models

Crash Movement	Final Model	B0 Coefficient	Model Parameters	Error Structure	P-Value
Loss of control crashes (NZ Types C and D)					
Loss of control crashes all-day model: flow-only	$A_{\text{Loss of control}} = B_0 \times q^{0.668}$	$B_0 = 2.49E-04$			
Loss of control crashes (NZ Types C and D)	$A_{\text{Loss of control}} = B_0 \times q^{0.541} \times \exp(0.144 \times \text{Number of approaching lanes}) \times (\text{Cycle time})^{-0.704} \times (\text{Degree of saturation})^{0.447} \times F_{\text{Residential}} \times F_{\text{Split Phasing}} \times F_{\text{Upstream parking}} \times F_{\text{Exit merge}} \times F_{\text{FLT}} \times F_{\text{High speed}} \times F_{\text{Approach bus bay}}$	B_0 (Auckland) 2.65E-02 B_0 (Wellington) 2.44E-02 B_0 (Christchurch) 9.12E-02 B_0 (Hamilton) 1.31E-02 B_0 (Dunedin) 1.11E-01 B_0 (Melbourne) 3.04E-02	F _{Split Phasing} 2.47 F _{Upstream parking} 0.58 F _{Exit merge} 1.47 F _{FLT} 1.17 F _{High speed} 1.57 F _{Approach bus bay} 1.60 F _{Residential} 0.75	Negative Binomial	0.062
Other crashes					
Other crashes	$A_{\text{Other}} = B_0 \times q^{0.262} \times (\text{Approach width})^{0.027} \times (\text{Cycle time})^{0.354} \times F_{\text{FLT}} \times F_{\text{Coordinated}} \times F_{\text{Shared turns}} \times F_{\text{Split phasing}} \times F_{\text{Adv detector}} \times F_{\text{High speed}} \times F_{\text{Approach bus bay}} \times F_{\text{Upstream parking}} \times F_{\text{Exit merge}} \times F_{\text{Commercial}}$	B_0 (Auckland) 1.87E-03 B_0 (Wellington) 1.46E-03 B_0 (Christchurch) 2.32E-03 B_0 (Hamilton) 2.02E-03 B_0 (Dunedin) 2.38E-03 B_0 (Melbourne) 1.55E-03	F _{Split Phasing} 1.21 F _{Coordinated} 0.71 F _{Shared turns} 1.26 F _{Adv detector} 0.44 F _{High speed} 1.98 F _{FLT} 1.16 F _{Approach bus bay} 1.27 F _{Upstream parking} 0.70 F _{Exit merge} 0.65 F _{Commercial} 1.83		

the cycle time can result in improved safety. Fewer loss of control crashes are observed at approaches with parking within 100m of the limit line, suggesting more caution on the part of drivers approaching the intersection. Use of split phasing results in a large increase in crashes, while the presence of an exit merge, free left turn lane, upstream bus bay (within 100m) and speed limit of 80kph or more also cause more loss of control crashes. Sites located in residential areas were observed to have fewer crashes as compared to those in commercial or industrial zones.

A range of factors appear to be important in the ‘other’ model, which is to be expected given the variety of crash types included in this model. Some of the key results of this model suggest that longer cycle times, split phasing, shared left/through or through/right lanes, high speed environments and upstream bus bays within 100m increase crashes, while signal coordination, parking within 100m of the limit line and exit merges reduce crashes.

Pedestrian crashes

Table 7 shows the models that were developed for crashes between pedestrians and motor-vehicles at traffic signals. There are two key types, right angle crossing (Type NA and NB) and right turn crossing (Type ND and NF). Right angle crashes involve a straight through vehicle hitting a pedestrian crossing at ninety degrees, either from left or right. It is not possible with the New Zealand crash coding to distinguish between nearside and far-side crashes at intersections. Right turn crossing crashes involve a right turning driver hitting a pedestrian crossing the road into which they are turning.

The coefficients for traffic volume and pedestrian volume are similar. Wider approaches are predicted to have more right angle crossing crashes. The variable coefficients for cycle time and all-red time suggest that increasing the length of the signal cycle results in more pedestrian crashes, possibly as a result of pedestrian frustration. A split signal phasing arrangement, presence of a raised median and cycle facilities on the approach result in reduced crash numbers.

The variation in B₀ values for Auckland and Melbourne are observed to be similar. A separate model for the Auckland and Melbourne sites was thus developed to limit some of the variation that is apparent in the all-city model. The coefficient of total approach volume, q, is observed to be lower for the Auckland/Melbourne model as compared to the model for all cities. A split phasing arrangement also shows a higher benefit at the Auckland and Melbourne intersections. The values of the other variables are similar to those found in the model for all cities.

The right turning crossing model shows that the pedestrian volume is a more important factor than motor vehicle volume in crashes. Longer cycle times are observed to reduce crashes, however longer amber times result in an increase in crashes. Fully protected right turns are quite beneficial from a safety perspective, while coordinated signals usually have more crashes. The presence of a median for crossing pedestrians was not found to have a significant effect on safety.

Table 7. Pedestrian crash models

Crash Movement	Final Model	B0 Coefficient	Model Parameters	Error Structure	P-Value
Right angle crashes: flow only	$A_{NA,NB} = B_0 \times q^{0.40} \times p^{0.42}$	B0 = 1.69E-03			
Right angle crashes (NZ Type NA and NB)	$A_{NA,NB} = B_0 \times q^{0.314} \times p^{0.364} \times \exp(0.16 \times \text{Number of approaching lanes}) \times (\text{All-red time})^{0.61} \times (\text{Cycle time})^{0.610} \times F_{\text{Cycle facilities}} \times F_{\text{Shared turns}} \times F_{\text{Split phasing}} \times F_{\text{Med island}}$	B0 (Auckland) 3.84E-05 B0 (Wellington) 1.28E-05 B0 (Christchurch) 5.30E-05 B0 (Hamilton) 5.94E-05 B0 (Dunedin) 8.90E-05 B0 (Melbourne) 3.39E-05	FCycle facilities 0.513 FShared turns 1.321 FSplit phasing 0.741 FMed island 0.767	Negative Binomial	0.036
Auckland and Melbourne model	$A_{NA,NB} = B_0 \times q^{0.188} \times p^{0.406} \times \exp(0.275 \times \text{Number of approaching lanes}) \times (\text{All-red time})^{0.444} \times (\text{Cycle time})^{0.646} \times F_{\text{Cycle facilities}} \times F_{\text{Shared turns}} \times F_{\text{Split phasing}} \times F_{\text{Med island}}$	B0 1.84E-04	FCycle facilities 0.673 FShared turns 1.414 FSplit phasing 0.550 FMed island 0.710	Poisson	0.29
Right turning crashes: flow only	$A_{ND,NF} = B_0 \times q_1^{0.11} \times p_{\text{side road}}^{0.22}$	B0 = 1.80E-02			
Right turning crashes (NZ Type ND and NF)	$A_{ND,NF} = B_0 \times q_1^{0.093} \times p^{0.172} \times (\text{Cycle time})^{0.579} \times (\text{Amber time})^{0.837} \times F_{\text{Full RT Protection}} \times F_{\text{Residential}} \times F_{\text{Coordinated}} \times F_{\text{Med island}}$	B0 (Auckland) 3.10E-02 B0 (Wellington) 1.03E-01 B0 (Christchurch) 1.09E-01 B0 (Hamilton) 1.93E-02 B0 (Dunedin) 2.24E-01	FFull RT Protection 0.63 FResidential 0.57 FCoordinated 1.24 FMed island 0.99	Negative Binomial	0.056

Table 8. Effect of intersection parameters on motor vehicle crashes

Parameter	Right angle	Right-turn-against	Loss of control	Rear end		
	All cities, whole day	All cities, whole day	Loss of control	Small intersections	Medium intersections	Large intersections
Higher traffic volume	↑		□	□	□	□
Higher right turning traffic volume		□				
Higher degree of saturation		□	□			
Larger intersections	↑					
Number of approaching lanes			□		□	□
Number of through lanes		□				
Longer cycle time	↓	□	□			
Longer all-red time	↓					
Longer lost time				□	□	□
Full right turn protection		□				
Split phasing	↓		□	□	□	□
Mast arm	↓					
Coordinated signals	↑					
Advance detector	↑					
Shared turns	↑					
Shared right turn		□				
Raised median / central island	↓	□				
Length of right turn bay / lane		□		□		□
Free left turn for motor vehicles			□	□	□	□
Exit merge			□			
Raised median / central island		□				
Cycle facilities		□		□	□	□
Upstream bus bay within 100m			□	□	□	
Upstream parking			□			
High speed limit (>=80kph)			□		□	

Discussion, conclusions and findings

An advantage of building crash prediction models for the different crash types at traffic signals is that this provides a holistic overview of safety at such intersections. The effects of various intersection features and treatments have a positive effect on safety of certain crash types, while negatively affecting other crash types. Table 8 provides a summary of results from the models that have been developed. It lists all factors that were found to be significant in one or more of the models and whether the factor led to an increase (red), decrease (green) or no effect (grey) on the rate of crashes of the respective crash types. The table shows those features that always have a positive or negative effect on crashes and those which can be either depending on the crash type.

A number of intersection parameters such as all-red time, shared turns and signal coordination were observed to affect a specific crash type. However, the model results also highlight the safety benefits obtained from longer cycle times and longer right turning bays across multiple crash types. On the other hand, free left turns for motor vehicles, more approaching lanes and near-saturated or over-saturated intersections were found to increase the risk of having a crash.

Phasing arrangements also figured prominently in the models. Presence of full right turn protection reduced right-turn-against crashes. Split phasing arrangements led to a reduction in right angle crashes and rear end crashes at larger intersections (those with three or more approach lanes and an intersection depth of 40m or greater), but an increase in loss of control crashes, other crashes and rear end crashes at small (one or two approach lanes, less than 25m) and medium intersections (all those not covered in the previous categories).

In addition to the models shown in Table 8, a combined Auckland and Melbourne model was developed for right-angle crashes, while peak period models were built for right angle, right-turn-against and rear end crashes. Coordinated signals showed mixed trends in Auckland and Melbourne together, where they were associated with more right angle crashes. This may be an outcome of drivers in larger cities being used to driving along coordinated corridors.

The presence of shared turns (i.e. both shared left/through or right/through lanes) had mixed effects, with an increase in right angle crashes for all cities taken together and in peak periods, but a reduction at the Auckland and Melbourne sites.

The cycle data collected as part of this study proved insufficient for developing crash prediction models for the prominent cycle crash types. There is a need for more and better quality cycle data from signalised intersections in New Zealand. Future studies should ideally consider a larger sample set for the analysis of cycle crashes. Data from 102 signalised intersections is already available as part of research conducted for Austroads by Turner et al. [10]. There is scope for building upon this data to include additional sites as well as intersection phasing information for the existing intersections. This will enable a more comprehensive dataset to be built which can be drawn upon for future studies.

Appendix A – New Zealand crash coding diagram

Land Transport NZ
 For use with crash data from CAS (Version 2.4 February 2005)

TYPE	A	B	C	D	E	F	G	O
A	OVER-TAKING AND LANE CHANGE	HEAD ON	LOST CONTROL ON OFF ROAD (STRAIGHT ROADS)	CORNERING	COLLISION WITH OBSTRUCTION	REAR END	TURNING VERSUS SAME DIRECTION	CROSSING (NO TURNING)
B	HEAD ON	COLLISION WITH OBSTRUCTION	REAR END	TURNING VERSUS SAME DIRECTION	CROSSING (NO TURNING)	CROSSING (VEHICLE TURNING)	MERGING	RIGHT TURN AGAINST
C	LOST CONTROL ON OFF ROAD (STRAIGHT ROADS)	CORNERING	COLLISION WITH OBSTRUCTION	REAR END	TURNING VERSUS SAME DIRECTION	CROSSING (NO TURNING)	CROSSING (VEHICLE TURNING)	MERGING
D	CORNERING	COLLISION WITH OBSTRUCTION	REAR END	TURNING VERSUS SAME DIRECTION	CROSSING (NO TURNING)	CROSSING (VEHICLE TURNING)	MERGING	RIGHT TURN AGAINST
E	COLLISION WITH OBSTRUCTION	REAR END	TURNING VERSUS SAME DIRECTION	CROSSING (NO TURNING)	CROSSING (VEHICLE TURNING)	MERGING	RIGHT TURN AGAINST	MERGE/VEHICLE
F	REAR END	TURNING VERSUS SAME DIRECTION	CROSSING (NO TURNING)	CROSSING (VEHICLE TURNING)	MERGING	RIGHT TURN AGAINST	MERGE/VEHICLE	PEDESTRIANS CROSSING ROAD
G	TURNING VERSUS SAME DIRECTION	CROSSING (NO TURNING)	CROSSING (VEHICLE TURNING)	MERGING	RIGHT TURN AGAINST	MERGE/VEHICLE	PEDESTRIANS OTHER	PEDESTRIANS OTHER
H	CROSSING (NO TURNING)	CROSSING (VEHICLE TURNING)	MERGING	RIGHT TURN AGAINST	MERGE/VEHICLE	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER
J	CROSSING (VEHICLE TURNING)	MERGING	RIGHT TURN AGAINST	MERGE/VEHICLE	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER
K	MERGING	RIGHT TURN AGAINST	MERGE/VEHICLE	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER
L	RIGHT TURN AGAINST	MERGE/VEHICLE	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER
M	MERGE/VEHICLE	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER
N	PEDESTRIANS CROSSING ROAD	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER
P	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER
Q	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER	PEDESTRIANS OTHER

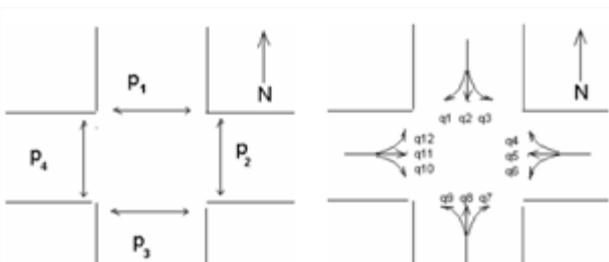
* = Movement applies for left and right hand bends, curves or turns

The following table presents each of the variables used in the models and their units. This includes continuous variables and dummy variables (those which are either on or off).

Unit Type	Variable Description	Units	
Continuous Variables	Number of approach lanes	1,2,3 etc..	
	Intersection depth	m	
	Approach width (entry only)	m	
	Length of right turn (RT) bay	m	
	Cycle time	seconds	
	Lost time (or inter-green – red and amber)	seconds	
	All-red time	seconds	
	Amber time	seconds	
	Degree of saturation – during peak period	Ratio	
	Dummy Variables	Split phasing (or standard)	Type
		Mast arm	Present
		Coordinated signals (or not)	used
Advanced (adv) detectors (or not)		Present	
Shared turns (left with through or right with through)		Present	
Median (med) island		Present	
Shared right turn (with through)		Present	
Full right turn (RT) protection (phase) on approach		Present	
Cycle facilities provided		Present	
Bus bay on approach		Present	
Free left turn provided		Present	
Standard phasing (nor coordinated)		used	
High speed approach (above 70kph)	or low		
Commercial development (or other development type)	Type		
Residential development (or other development type)	Type		
Upstream parking provided within intersection	Present		
Exit Merge	Present		

Appendix B – Data dictionary (variable names and units)

The two figures below show the four pedestrian phases around a four leg (approach) intersection (P₁ to P₄) and the 12 traffic flow movements at a cross-roads (q₁ to q₁₂). A similar approach can be used to define the pedestrian and traffic flows at T-junctions.



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Use of Kloeden et al's relative risk curves and confidence limits to estimate crashes attributable to low and high level speeding

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Abstract

Kloeden et al.'s relative risk relationships have been used in conjunction with vehicle speed measurements to estimate the relative frequency of casualty crashes associated with each speed range. Risks associated with high speeds had generally been ignored because of uncertainty about the relationships. This study estimates the relative crash frequencies using the confidence limits for the relative risks on urban 60 km/h limit roads. The estimated relative risks were also adjusted to reflect the increased probability of serious injury outcomes associated with increased speed. The concept of "population attributable risk" was used to estimate the fraction of crashes attributable to speeding in each illegal speed range. The estimated attributable fraction of casualty crashes was found to be higher for speeds above 80 km/h than speeds in the 60 to 70 km/h range, and higher again when the attributable fractions for serious casualty crashes were estimated. However, the results need to be tempered by the wide confidence limits associated with

Kloeden et al's relative risk relationship at high speeds on 60 km/h limit roads.

Keywords

Speeding, Relative risk, Population attributable risk, Attributable fraction

Introduction

Estimates of the relative risk of a casualty crash related to the travel speed of vehicles provide a valuable link between speed observations and crashes in the same road environment. It is possible to predict the crashes associated with each speed range on road and thus consider countermeasures focused on the speeds that make the highest contribution to road trauma. This study made use of Kloeden et al.'s [1] relative risk relationship for urban 60 km/h limit roads in a way that allowed the full range of on-road speeds to be analysed for the first time, including very high speeds. Previous researchers have generally not analysed very high speeds in this way.

Kloeden et al. [1] re-analysed data previously collected [2] on 151 vehicles' pre-crash travel speeds and 604 matched control vehicle speeds to determine the following relationship between the relative risk of a casualty crash and free speed (v) in 60 km/h speed limit zones:

$$RR = \exp(-0.822957835 - 0.083680149*v + 0.001623269*v^2) \quad (1)$$

Free speed was defined as unimpeded travel speed without any constraint by other traffic or slowing for manoeuvres. It was estimated that 56 per cent of casualty crashes in metropolitan 60 km/h speed zones involve a vehicle travelling at free speed [1].

Table 1 from Kloeden et al. [1] shows the estimates of the risk of a casualty crash, relative to the risk at 60 km/h, calculated from each travel speed using the relationship (1) above. Also shown in Table 1 are the 95% confidence limits within which the analysis has estimated that the true relationship between relative risk and travel speed lies, with 0.95 probability that it is included.

Figure 1 shows the fitted relationship and its confidence limits, viewed from two perspectives, the first covering travel speeds from 45 to 90 km/h, but truncated at an upper relative risk of 60, and the second only for speeds up to 75 km/h so that the relationship and confidence limits for speeds below 60 km/h can be more clearly seen.

Table 1: Kloeden et al.'s [1] relative risk relationship Free Travelling Speed and the Risk of Involvement in a Casualty Crash Relative to Travelling at 60 km/h in a 60 km/h Speed Limit Zone Using a Fitted Logistic Regression Model of Absolute Speed

Speed (km/h)	Relative Risk	Lower Limit*	Upper Limit*
45	0.27	0.13	0.49
50	0.39	0.26	0.54
55	0.60	0.50	0.69
60	1**	1	1
65	1.82	1.60	2.15
70	3.57	2.70	5.28
75	7.63	4.66	15.55
80	17.66	8.08	55.49
85	44.36	13.73	236.10
90	120.82	22.98	1222.70

*95% confidence limits of the estimated relative risk

** Relative risk arbitrarily set to 1 for 60 km/h

The criteria for inclusion of the crashed case vehicles in Kloeden et al.'s study included involvement in a crash from which "At least one person was transported from the crash scene by ambulance" [2]. Of the persons transported by ambulance, 12% were not medically treated, 56% were treated at hospital (presumably in Emergency Department), 3% by private doctor, 26% were admitted to hospital and 2.5% died. It is not known whether the case crashes were typical of casualty crashes in urban 60 km/h speed zones.

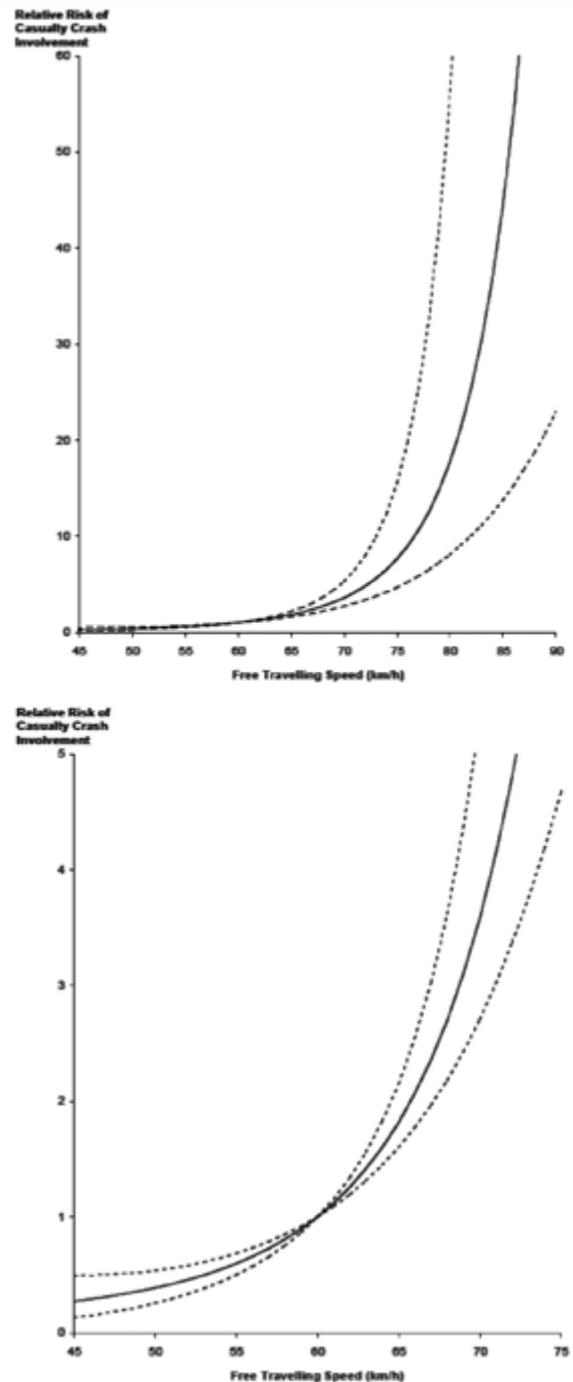


Figure 1: Relationship between relative risk and travel speed (two views) from Kloeden et al. [1]

Because of the strong effect of vehicle impact speed on the severity of injury outcome, it is important to note carefully the type of crash for which Kloeden et al.'s [1, 2] methods have measured the relative risk related to travel speed.

Diamantopoulou et al. [3] matched 149 of the 151 crashed vehicles from Kloeden et al.'s study [2] with South Australian Police crash reports. This matching found that 5% of the case crashes resulted in a fatality and 28% resulted in hospital admission. Higher pre-crash travel speeds were associated with the fatal crashes. The average travel speed of the vehicles involved in fatal crashes was 82.8 km/h (95% confidence interval: 72.8 to 92.8 km/h) compared with 67.7 km/h (95% CI: 63.0 to 72.4 km/h) for those involved in non-fatal casualty crashes.

The injury severity of the crash outcomes was related to the pre-crash travel speed. There was a statistically significant interaction between the injury severity of crash victims and increasing speed ranges (Figure 2). A total of 62.5% of the casualty crashes involving a vehicle travelling at more than 90 km/h in a 60 km/h speed limit zone resulted in a fatality or hospital admission.

Kloeden et al. [4] also developed a relationship between the relative risk of a casualty crash and free travel speed in rural speed limit zones. Because of the range of rural speed limits analysed, this study related relative risk to the difference between the free speed of the case vehicle and the average free speed of traffic in the same speed zone.

The criteria for inclusion of the crashed case vehicles in the rural study included involvement in a crash from which “At least one person ... was treated at, or admitted to, hospital or fatally injured”. Of the case crashes 23% were fatal and 46% resulted in hospital admission [4]. Thus in the rural study, the relative risk measured was that for a more severe casualty crash than that measured in urban 60 km/h speed zones [1, 2]. The risk related to free travel speed on rural roads is closer to the risk of crashes resulting in a person being killed or seriously injured (KSI), the latter descriptor of crash outcome being normally reserved for hospital admission, not just treated at or taken to hospital.

Previous use of risk estimates to weight speed observations

Kloeden et al.'s relationships have been used in conjunction with real speed observation data in a variety of ways. The general aim has been to estimate the (relative level of) casualty crashes associated with each level or range of illegal speeds in different speed limit environments.

D’Elia et al. [5] applied Kloeden et al.'s [1, 4] risk relationships to free speed data collected twice each year in Victoria during 1999 to 2004 for the purpose of comparing changes in expected crash levels, estimated from changed speed distributions, with direct measures of the crash effects of a major program of speeding-related enforcement/publicity/legislative initiatives during 2001-2002. For speeds measured at 60 km/h limit sites, the relationship (1)

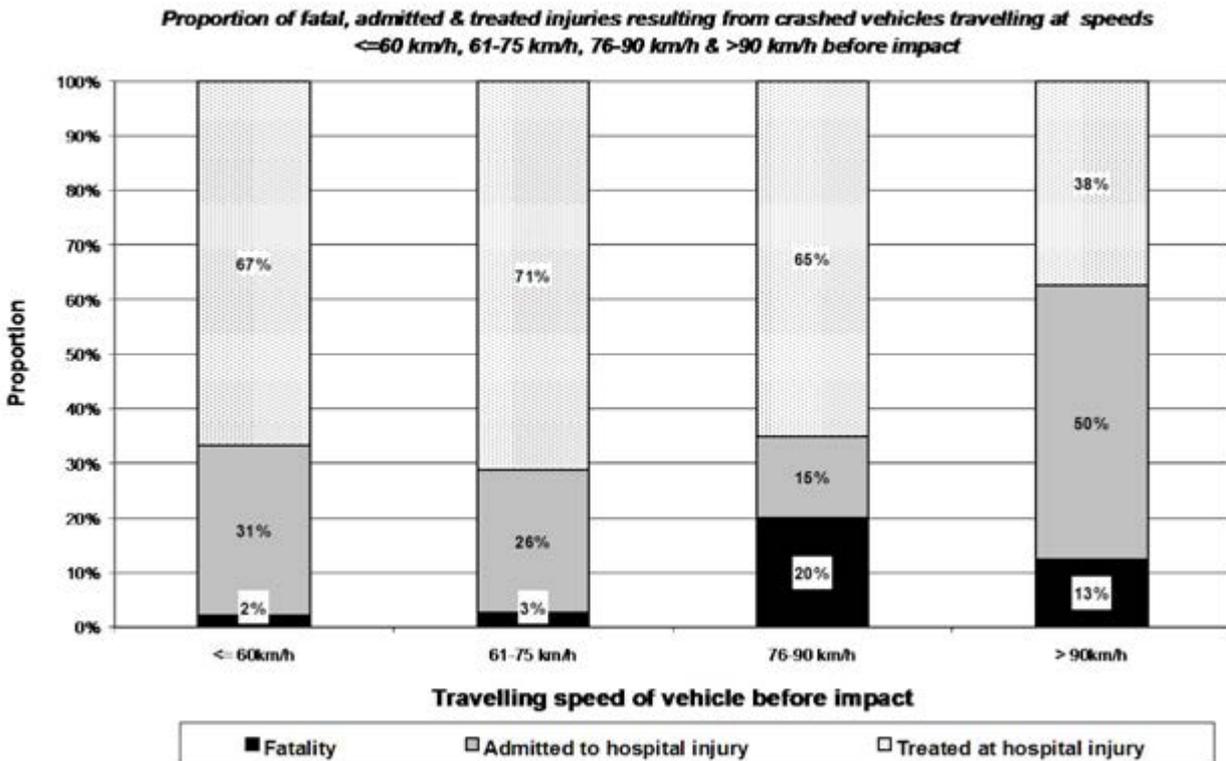


Figure 2: Injury severity related to pre-crash travel speed (60 km/h speed limit zones)

was used weight the speed observations in ranges up to and including “90 km/h or more” by the relative risk calculated at the mid-mark of the speed range. Speeds of 90 km/h or more (no more than 0.3% of observations) were assigned the relative risk for 90 km/h (120.8, from Table 1). The weighted speed observations were then summed (and standardised to the 1999 sum) to estimate a relative expected casualty crash frequency for each of the subsequent surveys during 2000 to 2004, compared with 1999.

Relationship (1) was also used, with 10 or 20 km/h shift of origin, to estimate the relative risks associated with the speeds measured at 70 and 80 km/h limit sites, respectively. For the observations measured at rural sites in different speed limit zones (80 to 110 km/h), Kloeden et al.’s [4] relationship was used instead. The analysis first calculated the zone-specific average free speed in each survey period and then used this to calculate the difference between each speed observation and the average before the rural speed-difference relationship was applied.

Gavin et al. [6] also applied Kloeden et al.’s [1, 4] relative risk relationships to speed observations collected on urban and rural roads in New South Wales during 2008. For the urban speed limit zone analyses, the alternative relationship developed by Kloeden et al. [1] based on the difference between the free speed of the case vehicle and the average free speed of traffic at the same crash location and time of week was used instead of relationship (1). The relative risk estimate was capped at that for 21 km/h speed-difference for speeds more than 20 km/h above the average speed (and capped at 41 km/h speed-difference in the rural analyses) because “[b]eyond these speeds the difference between the upper and lower confidence limits become increasingly large, and the relative risk increases to a level which appears unrealistically large”. Gavin et al. grouped the risk-weighted speed observations into bands of speed above the speed limit to examine the association with the estimated relative number of “casualty” crashes in each band. The estimated crashes in each illegal speed band were labelled as being “attributable” to the specific level of speeding. They concluded that the largest proportion of casualty crashes associated with speeding is attributable to drivers exceeding the speed limit by up to 10 km/h and that

drivers exceeding the speed limit by 11-20 km/h contribute the second highest proportion.

In a subsequent study, Gavin et al. [7] weighted the speed observations gathered before and after three major speed reduction initiatives in New South Wales for the purpose of comparing the changes in estimated relative casualty crashes with independent evaluations based on actual reported crashes. The speed observation data was available only in 10 km/h wide ranges and a separate process was applied to “smooth” the data into speed distributions for individual speeds. Again, Kloeden et al.’s [1, 4] relative risk relationships based on the difference between the free speed of the case vehicle and the average free speed of traffic in the same speed zone were used; the relationship depending on whether the initiative was relevant to urban or rural roads. Also again, the relative risk estimates were capped for high speeds, namely at 21 km/h above the speed limit on urban roads and 31 km/h above the limit on rural roads, for the same reasons as given by Gavin et al. [6].

Doecke et al. [8] used Kloeden et al.’s [1] relative risk relationship as a function of absolute speed (1) to weight speed observations from 50 and 60 km/h speed limit zones in South Australia during 2008. Only illegal speeds up to 20 km/h above the applicable speed limit were weighted because the “estimates of the relative risk of involvement in a casualty crash ... become less accurate at the higher speeds, being based on a very small number of crashes”. They estimated the expected relative frequency of casualty crashes for individual speeds 1 to 20 km/h above the speed limit and found that the frequency decreased consistently as the illegal speed increased.

Holman [9] also used Kloeden et al.’s [1] relationship with absolute speed in conjunction with speed observations from 60 km/h speed zones in Perth during 2010. The analysis was similar to the previous studies outlined above, except that he estimated the “population attributable risk” (PAR) associated with each illegal speed range, i.e. the fraction of crashes in 60 km/h speed zones attributable to the increased risk due to the speeding. Table 2 (solid borders) extracted from Holman [9] shows the calculation, followed by definitions of the symbols used in the heading of each column.

Table 2: Calculation of population attributable risk for speeds in 60 km/h zones in Perth during 2010

Speed of vehicle	p	v	RR	PAR	p*RR	>60 km/h p*RR %
<60 kph	0.534	60*	1.0	0.00	0.534	NA
60-69 kph	0.396	65	1.8	0.16	0.713	46.3%
70-79 kph	0.062	75	7.6	0.20	0.471	30.6%
80+ kph	0.008	85	44.4	0.16	0.355	23.1%
Total	1.000	NA	NA	0.52	2.073	100.0%

Definitions and formulae

p = proportion of total vehicles travelling in this speed interval in 2010.

v = mid-point of this speed interval in kph. *Exactly the legal limit of 60kph is used as the baseline for risk assessment.

RR = incidence rate of [casualty] crash at speed v relative to the legal speed limit of 60kph = $\text{Exp}[-0.822957835 - 0.083680149*v + 0.001623269*v^2]$.

PAR = population attributable risk in this speed interval = $p*(RR - 1)/(\sum p*(RR - 1) + 1)$ = proportion of [casualty crashes] attributable to speeding in this speed interval. (Walter [10])

The rationale for the concept of population attributable risk associated with crash risk factors is outlined by Elvik [11]. Its calculation for each level of a polytomous risk factor (as is the speed range factor used in Table 2) is defined by Walter [10], who also suggests labelling the result as the “attributable fraction” of crashes associated with speeding in the specific speed range. In essence, the attributable fraction is the proportion of crashes that are estimated to result from the increase in risk, relative to that at 60 km/h,

due to the speeding in the specific range. Some crashes apparently associated with speeding may be due to other factors that are present at legal as well as illegal speeds and that the speeding may only add to that inherent risk.

Also shown in Table 2 (cells with dashed borders) is the expected relative crash frequency ($p*RR$) typically calculated in previous studies [5, 6, 7, 8]. With this approach, it would be concluded that about twice the proportion of expected crashes associated with speeding lies in the 60-69 km/h range (46%) compared with the proportion above 80 km/h (23%). However, the population attributable risks estimated by Holman [9] suggest that the fraction of casualty crashes attributable to speeding in 60 km/h zones is about the same for 60-69 km/h and above 80 km/h (0.16 or 16% in each case).

Confidence limits on Kloeden et al.’s relative risk curves

Equation (1) indicates that the natural logarithm of the relative risk in urban 60 km/h zones is a quadratic function of travel speed. The natural logarithms (\ln) of the estimated relative risks and 95% confidence limits published by Kloeden et al. [1] (Table 1) are shown in Figure 3, together with quadratic functions fitted to each series. The coefficients of the quadratic function fitted to

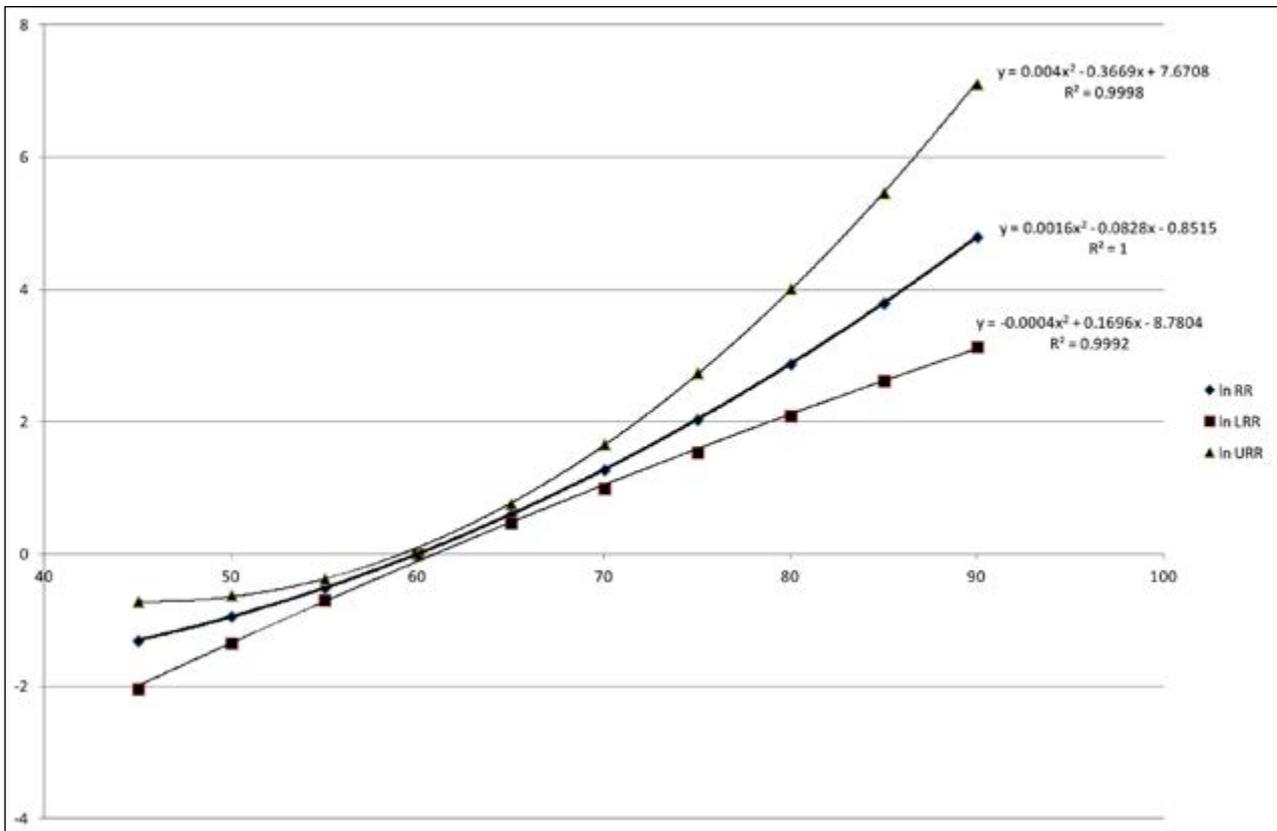


Figure 3: Natural logarithms of Kloeden et al.’s [1] relative risks (RR) and upper (URR) and lower (LRR) confidence limits versus travel speed in 60 km/h limit zones

$\ln(RR)$ are within rounding errors of those in equation (1). In subsequent analysis, equation (1) was used and the coefficients for $\ln(URR)$ and $\ln(LRR)$ were estimated with full precision.

Expected casualty crashes on 60 km/h roads in Perth

Kloeden et al.'s [1] relative risk relationship and the 95% confidence limits were used to estimate the expected relative casualty crashes and their upper and lower limits on 60 km/h roads in Perth, based on the same speed observations used by Holman [9]. The speed observations were classified in 5 km/h wide ranges (with reference speed at the mid-mark), except at the extremities where wider ranges were necessary and reference speeds were chosen as shown in Table 3. The expected relative casualty crashes and their limits are plotted in Figure 4.

Expected serious casualty crashes at illegal speeds

The relative casualty crashes in different speed ranges estimated in Table 3 do not reflect the increased injury severity of the case crashes in Kloeden et al.'s [1] study associated with the higher speeds (Figure 2). The risk of a serious crash outcome (death or hospital admission) of a casualty crash was estimated for each of the illegal speed ranges shown in Figure 2, relative to the risk at speeds in the range 61-75 km/h. These relative risks of serious outcome were used to inflate the risk of a casualty

crash at higher speeds to estimate the relative risk of a serious casualty crash (one resulting in a death or hospital admission) in Table 4.

This process of estimating the relative risks of a serious casualty crash from Kloeden et al.'s [1, 2] original data and analysis has the advantage of avoiding the absence of a clear definition of the injury severity profile of the casualty crashes to which Kloeden et al.'s relative risk relationship refers. The crash victims forming the basis of Figure 2 are from the crash cases in Kloeden et al.'s [1, 2] urban study, and the serious injury outcomes are those recorded on Police crash reports. The resulting estimates of the relative risk of a serious casualty crash related to travel speed are also more likely to be compatible with the relative risk of a (severe) casualty crash estimated in Kloeden et al.'s [4] study, which as indicated earlier, is closer to being related to the risk of a serious casualty crash.

The relative risk of a serious casualty crash, together with upper and lower limits estimated in the same way, were used to estimate the relative serious casualty crashes (and limits) from the observed speed distributions in the illegal speed ranges (Table 4 and Figure 5). The expected serious casualty crashes at travel speeds above 80 km/h exceed those associated with speeds in the 60-70 km/h range, though the confidence limits suggest that the estimates associated with the higher speeds are much less reliable.

Table 3: Expected relative casualty crashes and upper and lower confidence limits versus speed on 60 km/h speed zone roads in Perth, 2010

Speed range (km/h)	Mid-mark or reference speed	Frequency of speeds observed in 2010	Percent of speeds observed	Estimated relative risk (relative to 60 km/h)	Expected relative casualty crashes	Lower relative casualty crashes	Upper relative casualty crashes
0-30	20	6,978	1.05%	0.158	0.0017	0.0000	0.0728
30-40	35	23,571	3.55%	0.171	0.0061	0.0012	0.0274
40-45	42.5	24,935	3.75%	0.235	0.0088	0.0037	0.0190
45-50	47.5	43,520	6.55%	0.321	0.0210	0.0124	0.0323
50-55	52.5	85,892	12.93%	0.476	0.0616	0.0462	0.0755
55-60	57.5	169,940	25.58%	0.765	0.1957	0.1696	0.2167
60-65	62.5	175,230	26.37%	1.334	0.3517	0.3177	0.3959
65-70	67.5	88,133	13.26%	2.521	0.3344	0.2844	0.4312
70-75	72.5	31,134	4.69%	5.168	0.2422	0.1751	0.4031
75-80	77.5	9,846	1.48%	11.491	0.1703	0.0945	0.4123
80-90	85	4,343	0.65%	44.360	0.2900	0.0894	1.5406
90+	90	892	0.13%	120.82	0.1622	0.0298	1.690
Total		664,414	100.00%		1.846	1.224	5.316

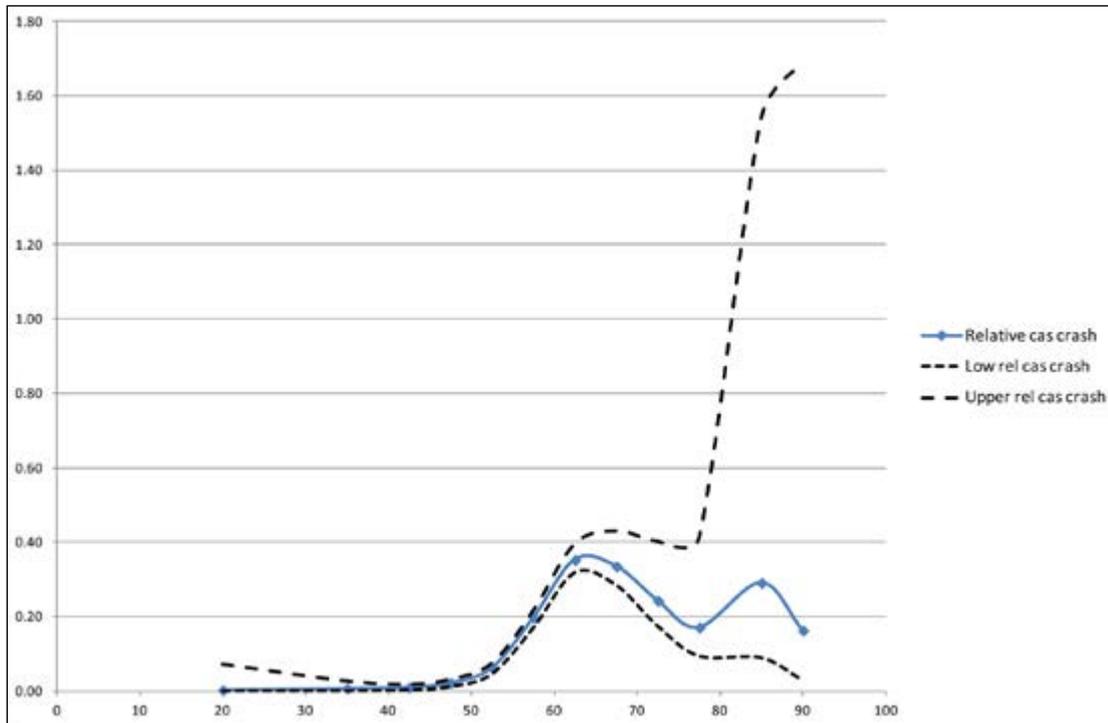


Figure 4: Expected relative casualty crashes and upper and lower limits on Perth 60 km/h limit roads

Table 4: Expected relative serious casualty crashes and upper and lower confidence limits versus speed on 60 km/h speed zone roads in Perth, 2010

Speed range (km/h)	Percent of speeds observed	Estimated relative risk of casualty crash (relative to 60 km/h)	Relative risk of serious crash outcome (relative to 61-75 km/h)	Estimated relative risk of serious casualty crash	Expected relative serious casualty crashes	Lower relative serious casualty crashes	Upper relative serious casualty crashes
60-65	26.37%	1.334	1.00	1.334	0.3517	0.3177	0.3959
65-70	13.26%	2.521	1.00	2.521	0.3344	0.2844	0.4312
70-75	4.69%	5.168	1.00	5.168	0.2422	0.1751	0.4031
75-80	1.48%	11.491	1.22	14.019	0.2078	0.1153	0.5030
80-90	0.65%	44.360	1.22	54.119	0.3538	0.1091	1.8795
90+	0.13%	120.82	2.17	262.18	0.3520	0.0646	3.666

Attributable fraction of casualty crashes

The attributable fraction of casualty crashes due to each range of speeds on Perth 60 km/h limit roads was calculated as defined by Walter [10], together with lower and upper limits again based on the confidence limits for Kloeden et al.'s [1] relationship (Table 5). The bottom part replicates Holman's [9] table (Table 2 here, with solid borders), except that more speeding categories are used. However the top part of Table 5 provides attributable fractions for speed ranges below the limit and, as would be expected, negative contributions of these speeds to crash attribution

are estimated. Walter [10] describes factors with a negative contribution as "protective factors" and PAR for these factors as "protective fractions".

From Table 5, it is estimated that 59% of casualty crashes are attributable to speeding. However, based on this analysis, it is estimated that only 16% are attributable to speeding in the 60-70 km/h range compared with 24% exceeding 80 km/h. The attributable fraction due to each speed range, both below and above the 60 km/h limit, is shown in Figure 6.

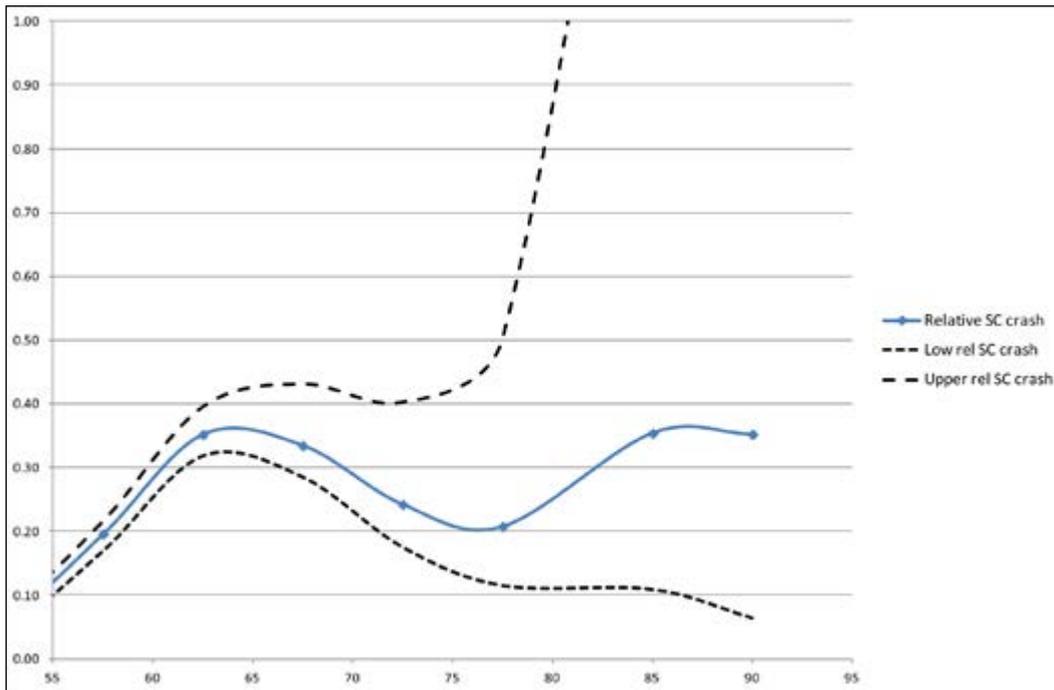


Figure 5: Expected relative serious casualty crashes associated with illegal speeds on Perth 60 km/h roads

Table 5: Attributable fraction of casualty crashes due to speeds on 60 km/h speed zone roads in Perth, 2010

Speed range (km/h)	Percent of speeds observed (p*100)	Estimated relative risk of casualty crash (RR)	Contribution to speed attributable fraction: p*(RR - 1)			Estimated population attributable risk (PAR) fraction of casualty crashes		
			Based on relative risk (RR)	Based on lower limit of relative risk (LRR)	Based on upper limit of relative risk (URR)	Attributable fraction (%)	Lower attributable fraction (%)	Upper attributable fraction (%)
0-30	1.05%	0.158	-0.0088	-0.0105	0.0623	-0.5%	-0.6%	3.4%
30-40	3.55%	0.171	-0.0294	-0.0342	-0.0081	-1.6%	-1.9%	-0.4%
40-45	3.75%	0.235	-0.0287	-0.0339	-0.0185	-1.6%	-1.8%	-1.0%
45-50	6.55%	0.321	-0.0445	-0.0532	-0.0332	-2.4%	-2.9%	-1.8%
50-55	12.93%	0.476	-0.0677	-0.0831	-0.0537	-3.7%	-4.5%	-2.9%
55-60	25.58%	0.765	-0.0601	-0.0862	-0.0391	-3.3%	-4.7%	-2.1%
60-65	26.37%	1.334	0.0880	0.0540	0.1322	4.8%	2.9%	7.2%
65-70	13.26%	2.521	0.2018	0.1517	0.2986	10.9%	8.2%	16.2%
70-75	4.69%	5.168	0.1953	0.1282	0.3563	10.6%	6.9%	19.3%
75-80	1.48%	11.491	0.1555	0.0797	0.3975	8.4%	4.3%	21.5%
80-90	0.65%	44.360	0.2834	0.0829	1.5341	15.4%	4.5%	83.1%
90+	0.13%	120.82	0.1609	0.0284	1.6882	8.7%	1.5%	91.5%

Attributable fraction of serious casualty crashes

The estimated relative risks of a serious casualty crash (Table 4) were used to estimate the attributable fraction

of these crashes due to illegal speeds in each speed range (Table 6). The estimated attributable fractions, together with upper and lower limits, are shown in Figure 7.

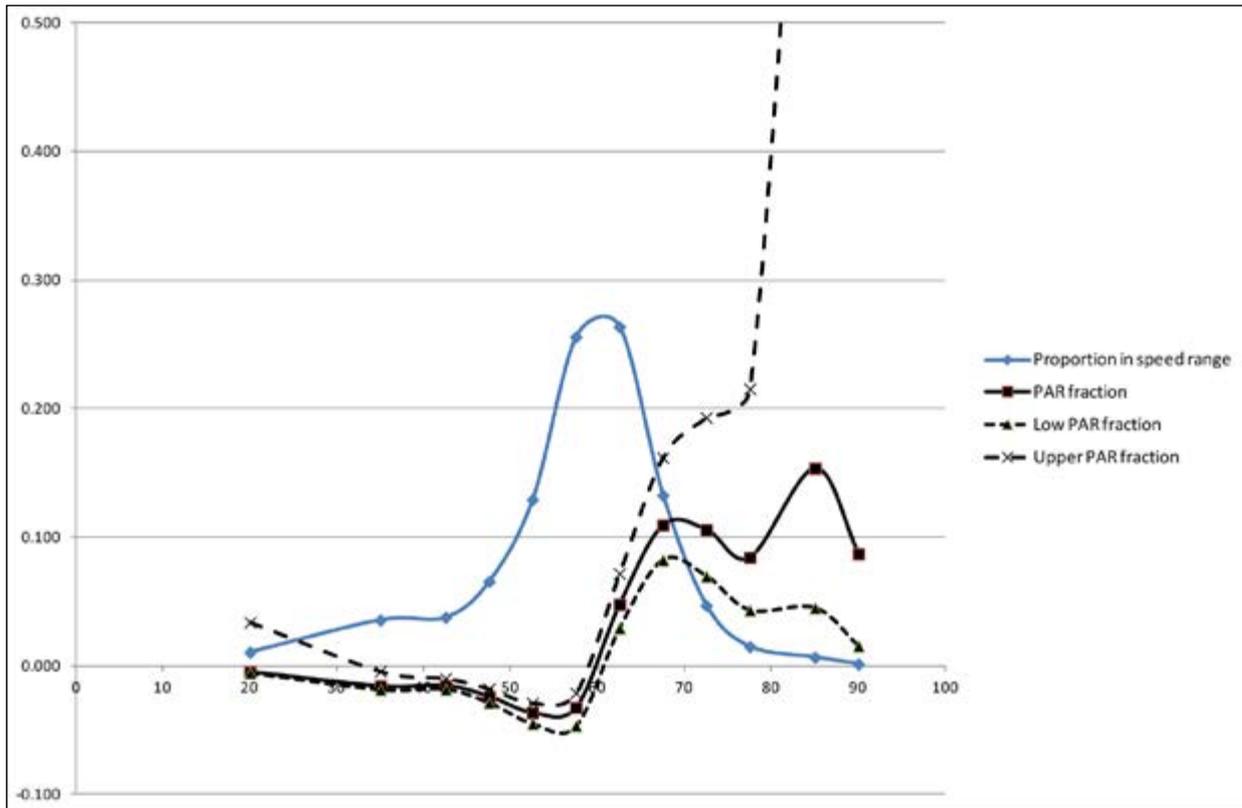


Figure 6: Estimated attributable fraction of casualty crashes for each speed range, plus high and low limits on the estimated attributable fractions

Table 6: Attributable fraction of serious casualty crashes due to speeding on 60 km/h speed zone roads in Perth, 2010

Speed range (km/h)	Percent of speeds observed (p*100)	Estimated relative risk of serious casualty crash (RR)	Contribution to speed attributable fraction: $p*(RR - 1)$			Estimated population attributable risk fraction of serious casualty crashes		
			Based on relative risk (RR)	Based on lower limit of relative risk (LRR)	Based on upper limit of relative risk (URR)	Attributable fraction (%)	Lower attributable fraction (%)	Upper attributable fraction (%)
60-65	26.37%	1.334	0.0880	0.0540	0.1322	3.7%	2.3%	5.6%
65-70	13.26%	2.521	0.2018	0.1517	0.2986	8.5%	6.4%	12.6%
70-75	4.69%	5.168	0.1953	0.1282	0.3563	8.2%	5.4%	15.0%
75-80	1.48%	14.019	0.1929	0.1005	0.4882	8.1%	4.2%	20.5%
80-90	0.65%	54.119	0.3472	0.1025	1.8730	14.6%	4.3%	78.8%
90+	0.13%	262.18	0.3506	0.0632	3.6650	14.8%	2.7%	154.3%*

* The fraction cannot exceed 100%. The calculated figure indicates that the upper limit is indeterminate.

Speeds on Queensland 60 km/h urban roads

The preceding analysis of risks associated with travel speeds on 60 km/h speed limit roads in Perth was based on 664,414 free speed observations collected during 2010. The analysis is sensitive to the reliability of the estimates of the proportion of vehicles in each of the high speed ranges.

While the sample was large, the estimated proportion of vehicles exceeding 90 km/h was only 0.13% and the estimated proportion in the 80 to 90 km/h range was 0.65%.

Information was available on the free speeds travelled on urban 60 km/h limit roads in Queensland during 2010 [12]. There had been a decrease in mean speeds and the

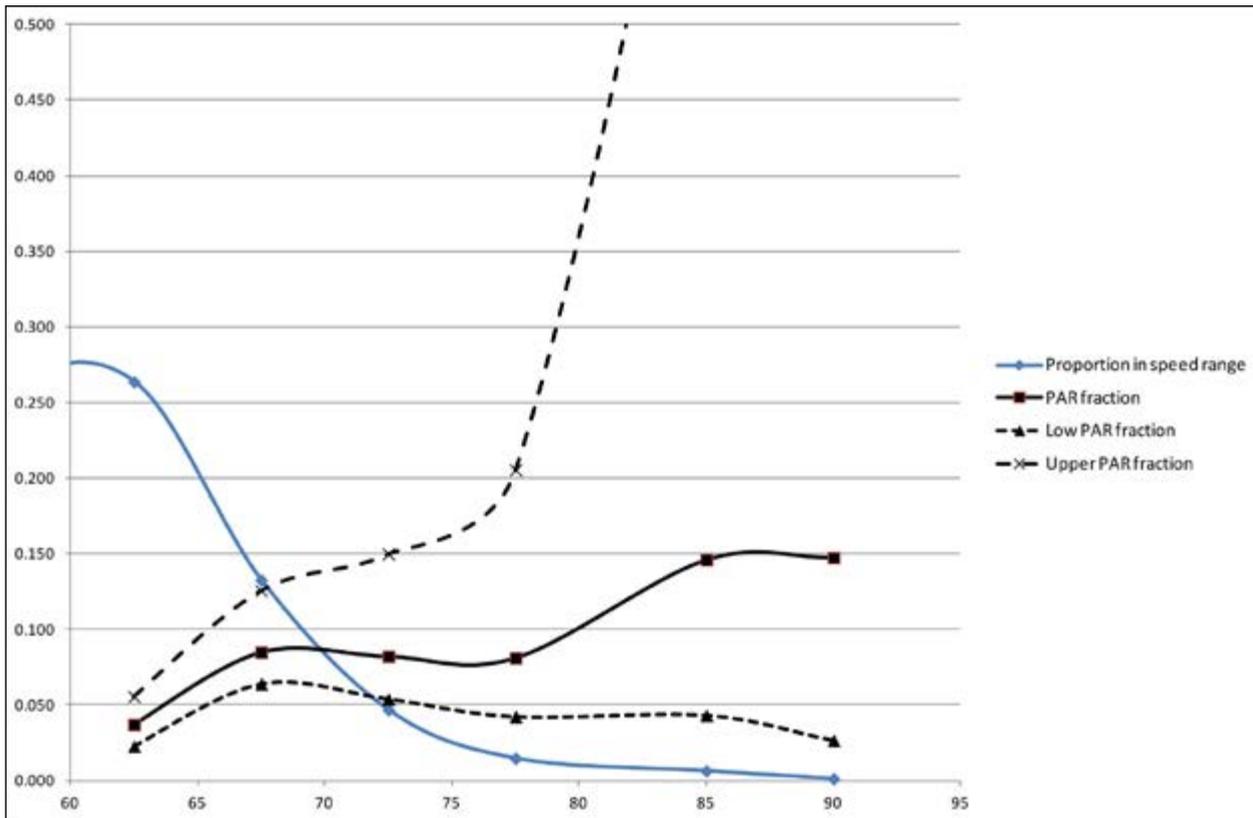


Figure 7: Estimated attributable fraction of serious casualty crashes for each illegal speed range, plus high and low limits on the estimated attributable fractions

Table 7: Attributable fraction (population attributable risk) of casualty crashes due to speeding on 60 km/h speed zone roads in Queensland, 2010

Speed range (km/h)	Percent of speeds observed	Estimated relative risk of casualty crash (relative to 60 km/h)	Attributable fraction (%)	Estimated lower attributable fraction (%)	Estimated upper attributable fraction (%)
60-65	24.01%	1.334	4.0%	2.5%	6.0%
65-70	10.93%	2.521	8.3%	6.3%	12.3%
70-75	4.18%	5.168	8.7%	5.7%	16.0%
75-80	1.62%	11.491	8.5%	4.4%	21.8%
80-90	0.93%	44.360	20.3%	5.9%	109.7%*
90+	0.21%	120.82	12.4%	2.2%	130.4%*

* The fraction cannot exceed 100%. The calculated figure indicates that the upper limit is indeterminate.

percentage exceeding the limit on these roads between 2009 and 2010, but speeds during 2010 were relatively stable. The two surveys in 2010 (May and November) recorded the free travel speeds of 2,532,322 vehicles on urban 60 km/h limit roads.

Using analysis identical to that described above for Perth 60 km/h limit roads, the attributable fraction of casualty crashes due to each speeding range on 60 km/h limit roads

in Queensland was estimated (Table 7). Although there was a larger proportion of vehicles not speeding on these roads in Queensland (58.1%) compared with Perth (53.4%), there were also larger proportions in the higher speed categories in Queensland. This translated into Queensland having a higher attributable fraction of casualty crashes due to speeding above 80 km/h (33%, summed from Table 7) compared with the same type of attributable fraction in Perth (24% from Table 5).

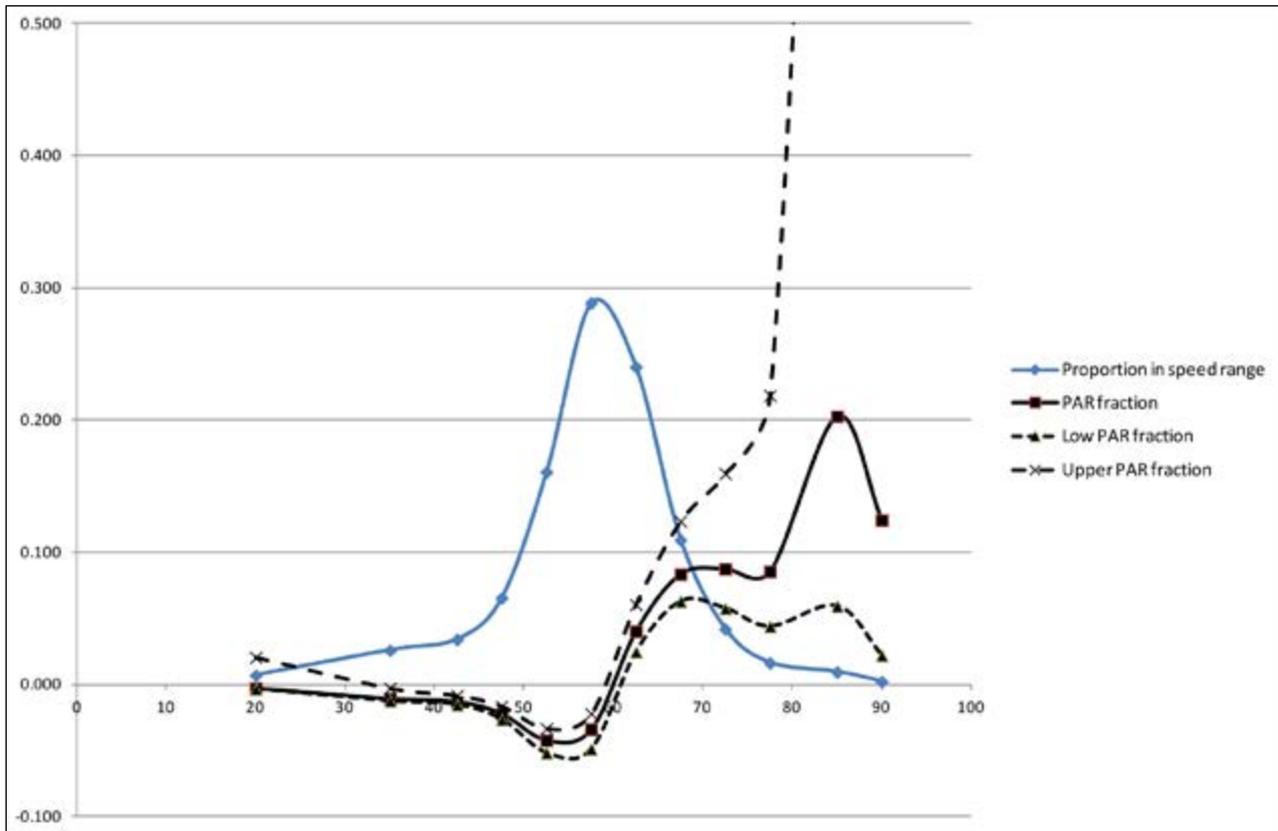


Figure 8: Estimated attributable fraction of casualty crashes for each speed range on 60 km/h zone roads in Queensland, plus high and low limits on the estimated attributable fractions

Table 8: Attributable fraction of serious casualty crashes due to speeding on 60 km/h speed zone roads in Queensland, 2010

Speed range (km/h)	Percent of speeds observed	Estimated relative risk of serious casualty crash	Attributable fraction (%)	Estimated lower attributable fraction (%)	Estimated upper attributable fraction (%)
60-65	24.01%	1.334	3.0%	1.8%	4.5%
65-70	10.93%	2.521	6.2%	4.7%	9.2%
70-75	4.18%	5.168	6.5%	4.3%	11.9%
75-80	1.62%	14.019	7.9%	4.1%	20.1%
80-90	0.93%	54.119	18.6%	5.5%	100.1%*
90+	0.21%	262.18	20.2%	3.6%	211.6%*

* The fraction cannot exceed 100%. The calculated figure indicates that the upper limit is indeterminate.

The attributable fractions in Queensland are shown in Figure 8, which can be compared with the same type of analysis for 60 km/h limit roads in Perth (Figure 6). This figure indicates that the speed ranges above 80 km/h can be attributed with a higher proportion of casualty crashes than each of the lower speeding ranges, or at least as great a proportion when the lower limits of these estimated attributable fractions are taken into account.

The analysis of the attributable fraction of serious casualty crashes due to illegal speeds on Queensland 60 km/h limit roads (Table 8) found an even higher fraction due to speeding above 80 km/h (39%) than the fraction of casualty crashes in the same speed range (33%). The lower limits of the attributable fraction for each speeding range (Figure 9) confirm that speeding in the 80-90 km/h range can be attributed with a higher proportion of serious casualty crashes than each of the lower speeding ranges.

Discussion and conclusions

Kloeden et al.'s [1, 2, 4] relative risk relationships have provided valuable opportunities for researchers to examine the share of crashes associated with each speed range by weighting speed observations by the relative risk in each range. However, in most cases [6, 7, 8, 9] the researchers have truncated Kloeden et al.'s relative risk estimates below the highest speeds because of concerns about the accuracy of the higher speed estimates. This study has attempted to avoid that limitation by making use of the confidence limits of the urban relative risk relationship as a function of absolute speed in 60 km/h speed limit zones [1]. However there is a limit to which the confidence limits were available and only those limits associated with 90 km/h speed were used in conjunction with speed observations of at least that speed.

This study has noted that the “casualty crashes” analysed by Kloeden et al. in their urban [1, 2] and rural [4] studies have different criteria for the case crash selection related to the transport to or treatment of persons at hospital. This is reflected in the injury severity profile of the crashes for which each risk relationship has been developed. Because of the availability of a previous study in which Kloeden et al.'s [2] case crashes had been matched with Police crash reports [3], it was possible to adjust the urban relative risk

relationship (and its confidence limits) to represent the risk of a serious casualty crash at speeds above the 60 km/h speed limit.

An interpretation of previous research may be to label the estimated casualty crash frequencies in each illegal speed range as being crashes due to the speeding behaviour. Holman's [9] important contribution to this type of analysis was to introduce the concept of “population attributable risk” associated with speeding as a risk factor, i.e. a factor that increases the risk of a casualty crash compared with the risk when not speeding. This concept was used in the new analysis in this study to better estimate the proportion of casualty crashes (“attributable fraction”) that is attributable to the increase in risk associated with each illegal speed range. The other previous researchers [5, 6, 7, 8] have estimated the relative number of casualty crashes associated with each speed range, but these crashes are not all attributable to the illegal speed in the range (particularly at low illegal speeds where the increase in relative risk is modest).

The analysis presented here suggests that the relative number of casualty crashes associated with speeds above 80 km/h on 60 km/h roads is at least as great as the number associated with illegal speeds in the 60 to 70 km/h range. Doecke et al.'s [8] analysis had suggested that the expected

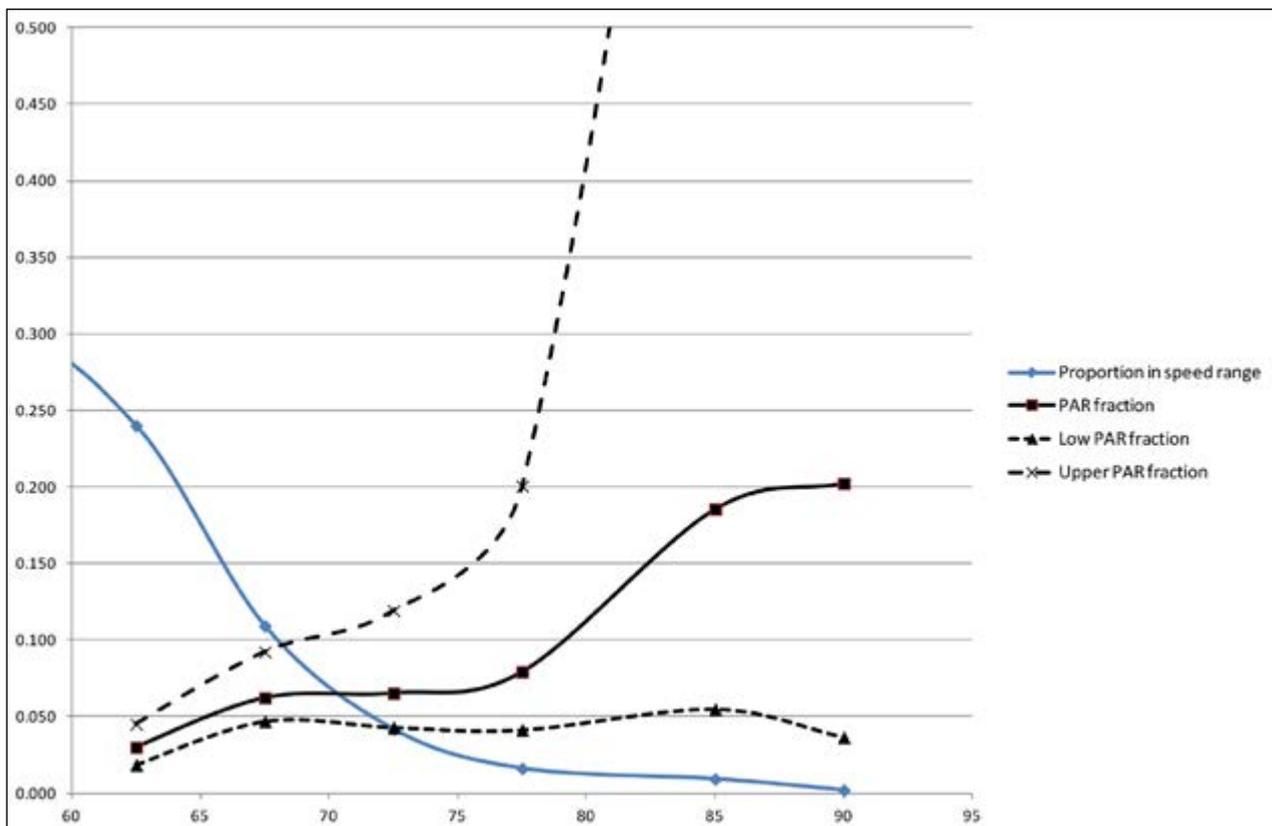


Figure 9: Estimated attributable fraction of serious casualty crashes for each illegal speed range on 60 km/h roads in Queensland, plus high and low limits on the estimated attributable fractions

number of casualty crashes falls consistently as illegal speed increases, but their analysis was truncated to speeds no greater than 80 km/h. When the attributable fraction of casualty crashes due to each illegal speeding range was estimated, the analysis found that it was higher for speeds above 80 km/h than speeds in the 60 to 70 km/h range. This difference was found to be greater on Queensland 60 km/h limit roads compared with those in Perth, and greater again when the attributable fractions for serious casualty crashes were estimated.

The conclusions of this study need to be tempered by the wide confidence limits associated with Kloeden et al.'s [1] relative risk relationship at high speeds on 60 km/h limit roads. Because of the importance of Kloeden et al.'s [1, 4] relationships for policy decisions about the relative contribution of low and high level speeding to road trauma, it is critical that research be undertaken to improve the reliability of relationships of this type. The urban relationship was based on 151 vehicles that crashed in Adelaide during 1995-1996. Intensive investigation of these crashes made it possible to reliably estimate the pre-crash travel speeds of these vehicles. Speed observations at the crash site were also required, but with modern technology the gathering of this information is not nearly as labour intensive as the crash investigations. With numerous police investigators and other crash researchers reviewing serious crashes throughout Australia, giving attention to estimating pre-crash travel speeds using technology such as in-vehicle Event Data Recorders, it should be possible to replicate Kloeden et al.'s [1, 2, 4] studies on a grander scale and provide the basis of more reliable relationships connecting speed and road trauma.

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Contributed articles

“Smarter travel @ work”: achieving road safety outcomes by reducing workplace travel

by A Bartram

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Introduction

The fundamental risk of being involved in a road crash stems not from elements of driver behaviour or the driving environment but rather from exposure to the road system in the first place [1]. Removing people from the road thus has an immediate impact on crashes. It is estimated that for every 1% reduction in vehicle kilometres travelled (VKT), there is a corresponding 1.4-1.8% reduction in the incidence of crashes [1, 2]. As such, interventions aimed at car trip reduction or encouraging the use of safer public transport are being strongly promoted by peak bodies such as the WHO as an effective way of preventing road traffic injury [3].

The ability of workplaces to impact on road safety by reducing car travel has been emphasised in ISO 39001, the new standard in road safety management systems. One of the key safety performance factors an organisation must consider when accrediting to ISO 39001 is safe journey planning: making conscious strategic choices about mode of transport, route choice, and whether to travel at all [4].

Smarter travel @ work is a voluntary travel behaviour change program offered to workplaces by the South Australian Department of Planning, Transport and Infrastructure (DPTI). The program works with workplaces around their staff commute and business travel, looking to reduce single occupant car use in favour of safer, greener and more active travel. By assisting workplaces to reduce the VKT of their staff, *smarter travel @ work* is contributing to improved road safety, as well as to other transport policy drivers such as reducing transport emissions, reducing congestion and improving use of public transport.

Using voluntary travel behaviour change to reduce vehicle kilometres travelled

DPTI has been delivering travel behaviour change programs to varying degrees since 1999. Initially these programs were aligned with Travelsmart SA, which was developed as the core action for the transport greenhouse action agenda. More recently the programs have evolved to use travel behaviour change tools and methodologies to encourage safer, greener and more active travel through reductions in car use. This is achieved through encouraging individuals to make more informed travel choices to substitute car trips with another option, reduce the distance travelled by car or eliminate the need for some journeys [5].

Voluntary behaviour change techniques as used by DPTI have been found to be quite effective in achieving VKT reduction. For example, TravelSmart Households engaged with households in the Western suburbs of Adelaide between 2006 and 2008. The project achieved an 18% reduction in VKT among the 22,103 participating households, in contrast to a 6% increase in VKT among non-participants [6]. This VKT reduction led to 505 fewer crashes in the project area across the three years of the project; an improvement in road safety valued at approximately \$19 million [7]. In addition to these road safety outcomes, DPTI's voluntary behaviour change programs have significant social, economic and environmental benefits [8].

Historically, the workplaces program had a strong public sector focus, working predominantly with large government departments based in the Adelaide CBD to help them meet transport greenhouse gas emission targets. In 2011, following a review, the program was re-launched as *smarter travel @ work*. This marked a move to also working with private workplaces within targeted local government areas, in partnership with the local council. The program is currently being delivered to workplaces in three local

government areas within metropolitan Adelaide, as well as one regional council.

To broaden the appeal of the program to workplaces within these locations, a more streamlined, client-centric process was developed. Instead of requiring workplaces to align to broad government targets around road safety or greenhouse emissions, the program is aimed towards the agendas of individual workplaces. This approach has made it significantly easier to recruit workplaces to participate [9]. The 26 workplaces currently participating in the program have joined *smarter travel @ work* for a variety of reasons; this has included a sustainability or road safety focus for some, but for many others the focus has been on cost savings, staff health and wellbeing, or relieving site-specific issues around parking. From DPTI's perspective it does not matter why the workplace is motivated to reduce VKT, it just matters that they are reducing VKT, as this will in turn lead to road safety improvements.

The *smarter travel @ work* process

The process for workplaces participating in the *smarter travel @ work* program is shown in Figure 1. This commences with a research phase, where current workplace travel patterns are explored; an implementation phase, where the workplace takes action to encourage staff to change their travel behaviours; and an evaluation phase, which assesses the impact these actions have had on travel.

Research

The key part of the research phase is a staff travel survey. The survey collects information relating to staff travel for work, including commuting, reasons for travel, route taken and potential interest in alternative travel arrangements. Information is also gathered from the workplace on things such as staff numbers, working hours, end of trip facilities and work travel policies. The information gathered is then analysed by DPTI and the key findings are presented back to the workplace, along with recommendations on initiatives that are likely to be successful.

Implementation

Following the research phase, the workplace then determines the delivery of initiatives. DPTI can assist in scoping, costing and refining programs. Workplaces can apply for a grant to support the implementation of their initiatives through DPTI's Community Grants program. They also join the *smarter travel @ work* network, which provides them the opportunity to be informed about what other workplaces are doing to support safer, greener and more active travel.

Evaluation

Twelve to eighteen months after the initial survey, once the workplace completes its actions or projects, staff are re-surveyed. This second survey is designed to measure:

- changes in car use and other modes;
- changes in perceptions;
- participation in initiatives and;
- future opportunities/ideas.

Following the second survey the workplace may decide to continue to deliver initiatives to achieve safer, greener or more active travel. They may also choose to continue to participate in the program with reduced DPTI support.

The first workplaces recruited under the re-launched *smarter travel @ work* program are currently reaching the evaluation stage of the process.

Changing work travel – workplace initiatives

Workplaces participating in the *smarter travel @ work* have implemented a variety of initiatives to support staff to undertake safer, greener and more active travel to and for work. Popular actions include journey planning, providing targeted travel information as part of induction and on an intranet or noticeboard, nominating travel friendly members of staff, providing public transport tickets for work trips and helping to organise carpooling.

For workplaces looking specifically to reduce work travel by car, common approaches are to promote public transport usage, to encourage shared car trips, or to use teleconferencing and video conferencing to remove the need to travel altogether. Below are a few case studies of workplaces that have successfully changed work travel.

Public transport: Australian Institute of Management, South Australia

In 2011 the Hindmarsh-based office of the Australian Institute of Management, South Australia (AIMSA) won the City of Charles Sturt Sustainable Business of the Year award. To build on this success and interest in sustainability, AIMSA joined *smarter travel @ work*. One of their aims was to increase public transport use among staff, contracted trainers and clients. Free public transport tickets are now offered for staff travelling to work meetings. With the help of DPTI, sample journey plans and maps were developed highlighting nearby public transport options and an information session for staff, trainers and clients was delivered. Feedback from AIMSA staff has been very positive, with staff discovering that travelling by

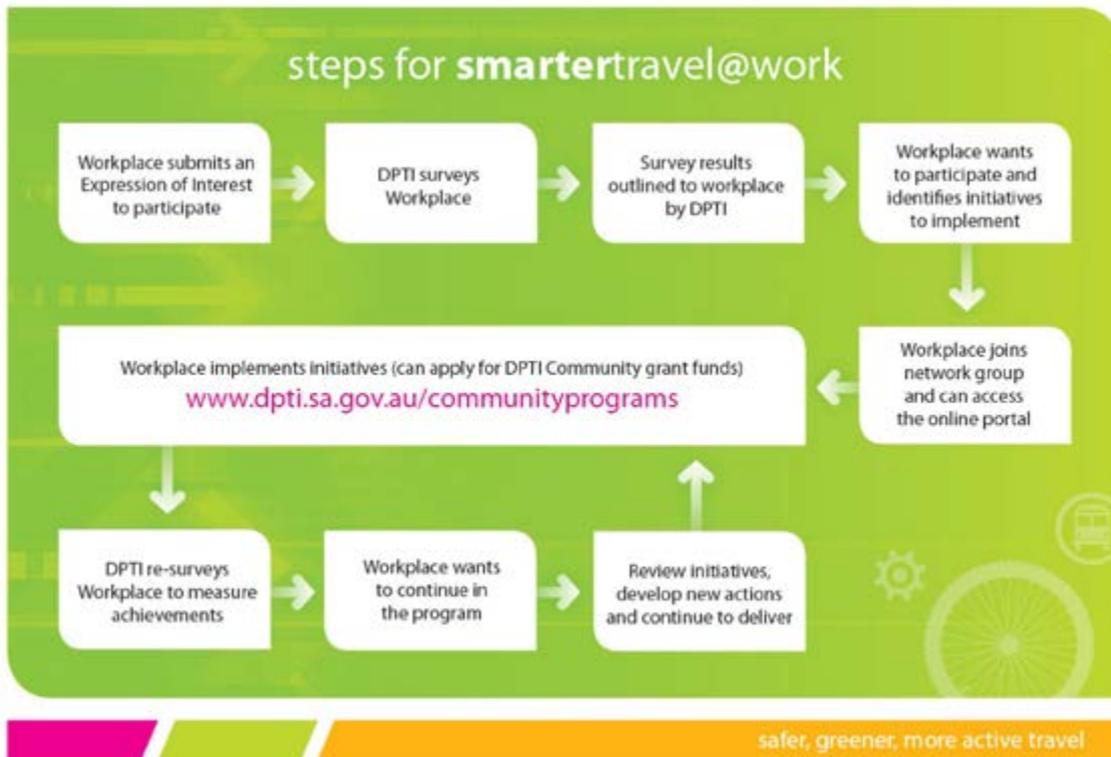


Figure 1. *smarter travel @ work* process

public transport provides an opportunity to work on the go. For AIMSAs itself, a move to public transport has resulted in reduced travel expenses and car park demands. In addition, it is a safer way to travel, with public transport carrying a much lower risk of injury incidents than driving [1].

Carpooling: Minda Inc.

Minda Inc. received a grant to purchase and implement a new electronic carpooling and fleet booking system, with the aim of reducing the size and use of the existing organisational car fleet of 90 vehicles. The system enables carpooling for work travel by linking staff members travelling to the same or nearby destination. It also links with local public transport to ensure staff members are provided with details of the safest, greenest and most active travel available. The project has resulted in a reduction of three fleet vehicles, which for Minda Inc. means an annual saving of between \$24,000 and \$30,000 and a saving of over 21,000 kilometres of car travel.

Web-based teleconferencing: Partners in Grain

Partners In Grain received a grant to assist with the introduction of webinar software. The grant was used to purchase and install the software and to provide training and information to staff. Installation of this system alone has meant that three of the four meetings conducted annually by Partners in Grain are now able to be hosted

online. This has already saved over 11,000 kilometres of car travel (with an estimated 8,454 car kilometres being saved each year). The project has been so successful that other organisations with a wide geographic spread, including Precision Agriculture Australia from Sydney and Riverine Plains Farming Systems from Victoria, have contacted the project coordinator with a view to also installing Webinar software in their organisations.

Future directions

DPTI takes a continuous improvement approach to all of its travel behaviour change programs. As evaluation results become available from the first workplaces to join *smarter travel @ work*, DPTI plans to review the program to identify ways to strengthen its approach to improving road safety. This may include exploring alignments with the road traffic safety management standard ISO 39001, as well as other Australian workplace road safety programs such as the National Road Safety Partnership Program [10].

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Corporate Road Safety: an opportunity to reduce the road toll through integrated Government policy

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Introduction

As a component of its National Road Safety Partnership Program draft strategy, the Australian National Transport Commission (NTC) recently consulted with stakeholders regarding the future for Corporate Road Safety in Australia, focusing on the major role that industry can play in improving road safety in Australia. This paper draws on and extends our submission, which can be seen in full on the NTC website [1].

Contemporary road safety focuses on key public safety factors, yet globally few governments have explored road safety from an occupational perspective. Road travel is the biggest traumatic cause of worker fatalities in most westernised countries, and an increasingly recognised injury and fatality burden in many others [2].

Corporate road safety is poorly addressed in existing Australian and other international regulatory regimes, with the work-road injury burden frequently falling between work and road safety policy and regulatory practice [2]. In contrast, Work Health and Safety (WHS) regimes are well established in many countries. It is proposed that these existing WHS systems could be effectively applied to work-road safety to provide a framework for co-ordinated policy and cost-effective strategies to reduce the road toll.

Based on experience and a systematic literature analysis, gaps were identified in existing policy and practice.

Evidence-based recommendations were then developed to focus on reducing the road toll and related business costs. These include the implementation of strategic corporate road safety systems underpinned by existing WHS data, systems, strategies and policies.

Corporate road safety research, policy and practice in Australia

Over the past 15 years a small number of researchers, practitioners and policy makers have provided significant evidence around the significance of corporate road safety in Australia. This clearly supports the societal, business, legal and financial case for action. From a financial perspective, Davey and Banks [3] and others before them (including Murray et al. [4]), have shown that the hidden costs of at-work collisions for society, organisations and individuals, are real and significant. It is clear that some evidence of sound organisational practice already exists in Australia, although to date little has made its way into the peer reviewed literature. Recent good practice examples include the Australasian Fleet Managers Association (AfMA) Fleet Safety and other award winners (www.afma.net) such as Roche Australia [5] and Redland Shire Council [6].

Despite these isolated examples, corporate road safety in Australia remains fragmented between the State and Federal agencies involved in road safety, compulsory third party insurance, workers compensation and work health

and safety, as well as law enforcement [6]. Many of these stakeholders and related researchers and agencies are isolated, and often appear to be working in separate silos.

It is imperative that key stakeholders in research, policy development and WHS/road safety practice (including industry and suppliers) collaborate in a national and integrated process to embrace corporate road safety. This would provide a powerful strategic initiative towards further reducing the road toll and lowering workplace fatalities and injuries, thereby significantly cutting injury and damage costs to industry and society.

Corporate road safety is an Occupational or Work Health and Safety (WHS) issue

In line with the strategic direction of the National Road Safety Plan, actions need to engage with a large proportion of Australian organisations. For example government (federal, state and local) is collectively the country's largest purchaser of vehicles, and one of the largest employers of contracted and sub-contracted organisations using the road. Government should therefore lead by example in terms of policy and practice in relation to its own corporate road safety.

The comprehensive enforcement of WHS and Chain of Responsibility (COR) requirements pertaining to business and government organisations as a means to engage smaller contractors in road safety, would be a good starting point. For example, supply chain partners could be required to: purchase only five-star vehicles; demonstrate robust driver recruitment, induction, risk assessment and controls; and, have monitoring programs for all their employees required to travel in the course of work.

Without regulatory inducements many organisations will not engage and implement corporate road safety strategies. Therefore, a more harmonised and robust interpretation, combined with integration and enforcement of existing Chain of Responsibility (COR), WHS and road traffic regulations are essential to achieve significant improvements in corporate road safety.

Furthermore, currently many gaps and inconsistencies are undermining the existing structures. These include inconsistent enforcement, WHS application and regulation, and communication to organisations; lack of accurate and detailed crash and licence data; inconsistency between heavy vehicle and occupational light vehicle regulation, and fragmented workers compensation and insurance structures [2]. All of these issues are compounded by the current parochial jurisdictional systems and the lack of standardisation or harmonisation across Australia.

The new reform incorporating the National Heavy Vehicle Regulator (for > 4.5 tonne) which began in January 2013 and manages enforcement of the Heavy Vehicle National Laws is a welcome initiative. Such regulations governing large and heavy vehicles are more extensive and rigorous than those governing small and light vehicles. WHS requirements also tend to focus on large and heavy vehicles.

As discussed by Stuckey and LaMontagne [7], such legislative changes and the good practices they support and encourage, have so far had minimal impact on the significant number of light and small commercial vehicles and cars being driven for work – although many good practice processes could be applied in a similar manner irrespective of vehicle type. Murray [8] focused more attention on the potential applications of WHS policy principles and good practice for corporate road safety in Australia, where vehicles on roads are recognised as a workplace, but as yet only limited regulation and enforcement has been undertaken to address related risks [2].

WHS compliance is a requirement of all organisations in all sectors, therefore a national harmonised corporate road safety WHS Code of Practice (COP), supported by communications, education and enforcement, is a good starting point to engage the vast majority of organisations whose people interact with the road. Such an approach should provide a clear minimum standard for everyone to work to – much like the joint Health and Safety Executive (HSE) and Department for Transport (DfT) '*Driving for Work*' guide in the UK, which was launched in 2003 [9]. This COP should be supported by closer collaboration between WHS agencies, Road Authorities and the Police in terms of enforcement and post event investigation. Similarly, existing transport and COR regulations are effective for larger vehicles, but more enforcement and a similar approach should also be considered for occupational light vehicles.

Such recommendations are not about developing a whole set of new systems. They are about using the systems which are already in place to improve the overall regulatory outcome. State level guidance documents already exist, such as in Victoria [10], which spell out the responsibilities clearly under Victorian OHS law. Given such existing frameworks, it is argued that Australia does not actually need another regulator, but rather enforcement of the existing regulation. All the WHS acts require risk identification, risk assessment, risk quantification and risk control. There is clear evidence of a quantifiable injury and fatality risk, a range of relevant risk factors – what is lacking is the efficient and effective enforcement of the prevailing regulation.

A COP should engage WHS professionals in corporate road safety and provide practical guidance for organisations to

achieve minimum Duty of Care obligations and standards. To some extent, this is already happening in relation to vehicles used off-road on traditional worksites. A COP would also provide WHS inspectors with guidelines when auditing and enforcing an organisation's WHS practices. There are a number of existing examples of enforcement (breaches of the COP in regards to managing plant) which can be used to support this approach. These include the following vehicle and fatigue based cases:

- http://www.safework.sa.gov.au/uploaded_files/20110526_mihalopoulos.pdf
- <http://www.theage.com.au/national/1000-charges-raft-of-road-charges-levelled-at-trucking-bosses-20120510-1yeez.html>
- <http://www.theage.com.au/victoria/justice-for-dead-brother-20100428-tsic.html>
- http://www.workcover.nsw.gov.au/formspublications/publications/Documents/health_aged_care_industries_minimising_fatigue_0230.pdf

These cases illustrate that WHS agencies and road authorities typically do get involved if apparent causation relates to a vehicle fault and or specific safety risk such as fatigue, which had not been systematically addressed by the organisation.

It also appears from the publicly available cases that such prosecutions generally occur in relation to heavy vehicles or vehicles driven by emergency service workers, where there is an overt public risk, or the vehicle is clearly being driven for work purposes – and generally where there has been a lot of publicity about potential risk factors in a sector prior to the event.

The jurisdiction of risky or hazardous driver behaviour is more typically enforced by the police focusing on fault, liability and negligence – and is generally not recognised or acknowledged as related to work, organisations or the purpose of journey in any way.

To summarise, corporate road safety, for all vehicles being driven for work irrespective of size or type, is both a road safety and a work health and safety issue. Like any complex matter, a combined approach of both 'soft' and 'hard' measures is required to make real change. Corporate road safety should be managed through the WHS legal and regulatory structures. A legal 'Duty of Care' compliance is required to protect the health and safety of workers driving for work purposes. This legal requirement is included in all Australian WHS acts, including the Model Work Health and Safety Act 2011 [11]. This duty of care applies to all employers, workers (regardless of work arrangement) and 'others' such as non-workers and the general public.

The potential benefits from a collaborative WHS and Road Safety Partnership at State, Territory and Commonwealth

levels need to be promoted widely. This is essentially building on the very significant human factors and behavioural change skills in road safety, whilst using the powerful regulatory tools available to the WHS authorities of Australia. State and Territory jurisdictions already have in place an Interagency Agreement or Memorandum of Understanding between the WHS and Workers' Compensation regulators throughout Australia, Road Authorities and the Police.

Currently, there does not appear to be a consistent approach for escalation to WHS regulators of work-related road traffic incidents - in particular for light vehicles. Also, fatalities are more likely to be escalated, whereas serious injuries are less likely or rarely escalated. Minor incidents that do not require police presence, should be recorded by an organisation as an incident regardless of the level of damage, as for any other type of WHS incident, and made available for inspection. Obtaining such collaboration between road enforcement and WHS agencies will require the building of a case by NTC though the relevant Ministerial Councils, to endorse a genuine national partnership that will capitalise on the workplace as a 'new frontier' for road safety improvements.

It is clear that this concept of 'escalation' of road safety to WHS regulation is implicit in the NTC's National Road Safety Partnership Program. Currently, it is not explicitly outlined as to how this interface between road safety regulation and WHS regulation would operate. Accordingly, a much stronger and genuinely regulatory approach needs to be made clear to enable the step change that is needed. The implementation of a harmonised pan-Australian WHS Code of Practice on Managing Risks for Work-related Vehicles would be the most responsible approach to underpin and practically support this outcome.

Other strategies to assist in improving compliance include access to driving licence data to allow checks on people required to drive as part of their work. This could bring many benefits to work-related road safety across the whole of Australia. The truck sector is already requesting it in Australia, and organisations in New South Wales and South Australia have systems in place which allow them to currently conduct online checks of individual licences of employees with their written consent.

If Australia could adopt a similar model to the well-established UK Driver and Vehicle Licensing Agency (DVLA) electronic check or the US Motor Vehicle Record (MVR) a great deal of bureaucracy could be reduced. Licence checks could provide the first step in risk assessment and benefit the many organisations in Australia which require their people to use the road as part of their work. This could assist them to check on-going driver road-law compliance and further develop risk based models for driver recruitment, management and monitoring.

Currently, many Government agencies in Australia appear to cite privacy and data security as reasons to not be proactive in making such data more readily available for WHS surveillance. Australia could learn a great deal from the more developed US, UK and New Zealand practices to institute such systems. As long as drivers provide explicit, freely given, fully informed consent, appropriate compliance and risk-based data could be transferred, stored and utilised in a secure environment. Based on the US and UK models, this approach also offers a potential income stream for the licencing authorities, which can sell the data to employers and third party intermediaries.

The NTC proposed National Road Safety Partnership Program is a welcome initiative, but its membership appears quite narrow and needs to be expanded to include mechanisms for other critical sectors and organisations to be involved in the on-going deliberations, including representation from some or all of the following:

- Australasian College of Road Safety
- Australasian Fleet Managers Association (AfMA)
- Safe Work Australia
- State, Commonwealth and Territory WHS agencies
- Workers Compensation Insurers
- Police
- Government fleets – which remain the biggest purchasers of vehicles in Australia
- Vehicle leasing, supply and finance sector – including manufacturers
- Bus and rail sector
- Lead researchers in the area of work-related road safety such as CARRS-Q, MUARC and other University based researchers
- Compulsory Third Party and private motor insurers
- Occupational Health and Safety Professional bodies including bodies represented by the Health and Safety Professionals Alliance (HaSPA)
- Other industry and professional bodies

Conclusion and recommendations

To be effective, workplace safety requires comprehensive regulatory regimes with significant enforcement. Corporate road safety is gaining recognition in many countries as a viable strategic focus to address the growing global road toll. In Australia, most initiatives result from individual employer-based strategies rather than systematic government regulatory interventions.

Corporate road safety should be managed through the existing WHS legal and regulatory structures in partnership with existing road safety programs.

It is recommended that:

1. A pan-Australia Code of Practice which addresses work-related road risk should be written and implemented as soon as possible.
2. A National work-related road risk management memorandum of understanding should be established between State and Commonwealth WHS agencies, Road Authorities, and Police Agencies to assist in the enforcement of corporate road safety obligations under current WHS laws.
3. The national road safety strategy and jurisdiction equivalents need to incorporate corporate road safety as part of on-going strategies.

These recommendations address occupational travel risks, and the possibilities for the application of integrated and systematic road-safety and WHS strategies. They present unique opportunities for significant reductions in the social and economic injury-burden, and approaches to managing related damage costs for participating nations and organisations. Systematic implementation at regulatory and industry levels should provide compliance, economic and risk management benefits to every workplace using road vehicles.

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Children locked in vehicles: implications for organisational and community safety

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Introduction

While state motoring clubs around Australia are well known for their motoring advocacy work and membership advantages, roadside assistance for broken down vehicles remains a key activity. The Royal Automobile Club of Queensland (RACQ) alone receives up to 4,000 calls for assistance each day from motorists. The majority of these calls will be associated with vehicle mechanical or electrical issues, but on average around 10 calls a day will be due to a baby, adult person or animal being accidentally locked in a vehicle.

These lock-in calls are almost always as a result of an unintentional act on the part of the driver. Typically the keys are given to the child to hold while the driver performs some other task. If the remote locking button has been pressed the locking system secures all closed doors leading to a situation where once the remaining door is closed the security system then completes its locking sequence, preventing the driver from gaining access to the vehicle. At this point the driver realises they have a highly stressful situation unfolding.

RACQ research has found that vehicle interior temperatures rise very rapidly and from around 19°C can reach the critical (according to medical authorities) temperature of 40°C in about eight minutes on a typical, clear summer day in Brisbane [1]. Peak cabin temperatures can go on to reach approximately double the ambient temperature [1].

Due to the risk to the health of the baby, adult or animal locked in the vehicle it becomes a matter of urgency that the locked-in person or animal is rescued as soon as possible. RACQ responds to such calls for assistance as a community service. This means that RACQ will assist as a priority any person, regardless of RACQ membership status given the safety risks to the individual or animal locked in the vehicle.

Responding to emergency calls of this nature increases the pressure on the RACQ and its staff. From the call centre staff who take the calls and arrange the Club's response, to the RACQ patrol staff who are despatched to attend the vehicle, there is a coordinated, prioritised approach to assisting the individual or animal locked in the vehicle as quickly as possible.

2011	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	YTD Total
BABY	153	174	231	209	218	217	199	218	197	244	182	192	2434
DAILY AVERAGE	4.94	6.21	7.45	6.97	7.03	7.23	6.42	7.03	6.57	7.87	6.07	6.19	

Figure 1: Baby locked in car calls and average daily calls per month 2011

The numbers: emergency lock in calls

In 2011, RACQ received 2,434 calls (average of 6.67 calls per day) related to babies or children locked in cars. October and March had the highest average number of calls per day, while January and November had slightly lower averages.

While the total number of baby/child locked in car calls represent only 0.2% of the total number of calls for assistance RACQ receives each year, the potential risk to the individuals locked in the vehicles means that these calls require immediate priority response.

Vehicle cabin temperatures initiate a priority response

Heat/sun stroke or thermic fever occurs when the human body's core temperature exceeds 40.5°C and is a life threatening emergency to prevent brain damage, organ failure or death [2]. Heat stroke can be brought on by a rise in the body's temperature, including from high environmental temperatures; and babies, young children and people over 75 years of age are at the highest risk [2].

RACQ has long been interested in vehicle cabin temperatures and in identifying a need for further research in this area, and has conducted a number of studies into vehicle cabin temperatures. The Club's first study, conducted by King and Negus in 1982, investigated the heating characteristics and variables of a number of vehicles [3]. The second study was conducted in 1995 by the Club's Traffic and Safety Department and focussed on the effects of vehicle design on heating characteristics of modern cars under typical Brisbane winter and summer conditions [4]. The third study, conducted by Manning

and Ewing in 2008-2009 replicated some of the previous studies, but also examined the effects of window tinting film and windscreen shades on heating [1].

Manning and Ewing's study [1] found that after having both a light and dark coloured Isuzu D-Max dual cab utility cabin temperatures normalised in an under-building car park with the air conditioning switched on (low fan speed) the temperatures of the vehicles rose from 19.2°C (light coloured vehicle) and 19.4°C (dark coloured vehicle) to:

- 30.4°C (ambient temperature) within 1.5 minutes;
- 40.5°C and 40.8°C in a further 6.5 minutes for the light and dark coloured vehicles respectively.

This rapid increase in temperature to critical heat stroke range means that any response to emergency vehicle lock-ins involving humans or animals must be treated with high priority to help reduce the likelihood of negative health outcomes for the individuals and/or animals involved.

How are the calls handled?

RACQ call centre

RACQ Service Consultants are trained in handling these emergency calls and will follow a set procedure, ensuring all details are collected and recorded accurately on the job. Formal induction and continuous training is crucial to ensure all RACQ Service Consultants are competent in delivering efficient service to members/callers. A training manual specific to handling emergency calls has been created for coaching Service Consultants during their initial road service training. The Service Consultants are advised that often the callers are quite distressed; therefore they should remain calm and take control of the call in order

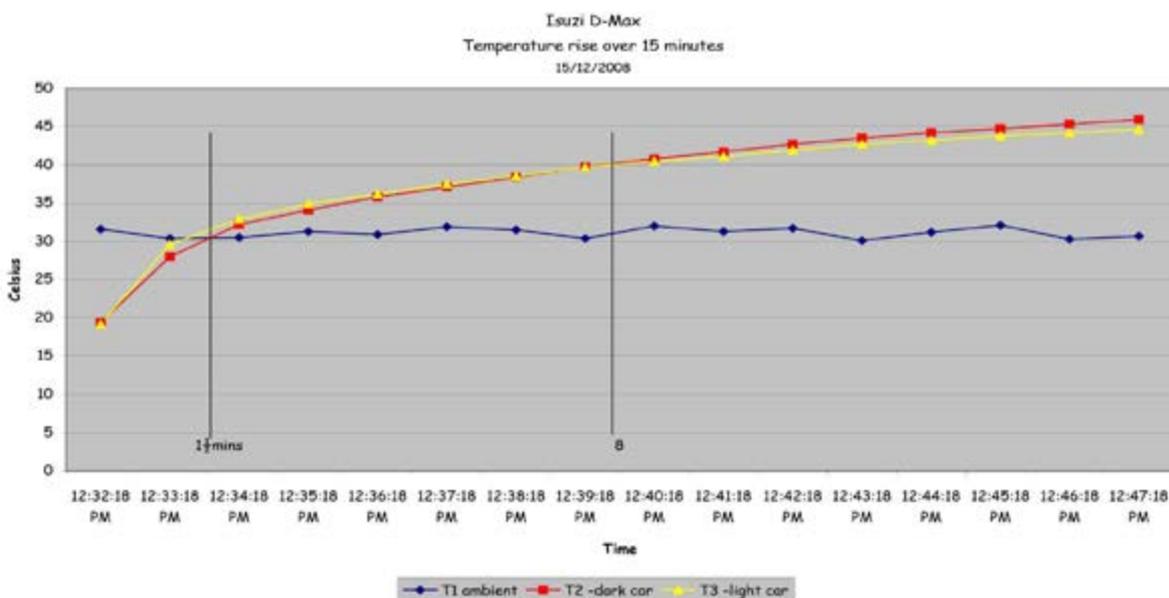


Figure 2. Temperature rise over 15 minutes in Isuzu D-Max utility

to gain the required information efficiently. By doing this, RACQ is able to despatch patrols to the job as quickly as possible.

During training, Service Consultants are provided examples of what to expect when handling an emergency call. Service Consultants are trained in the procedures for handling calls; are provided with ongoing training and development; and must pass an online assessment prior to completing live calls.

Procedures include checking details such as if the baby is distressed or has vomited; if the vehicle is in the sun; if the Ambulance Service should be notified; caller location and vehicle details.

Two RACQ patrols are dispatched wherever possible. The Field Support Officer notifies the Shift Leader which RACQ Patrols are attending and their Estimated Time of Arrival (ETA). Technical Support discusses the method of entry into the vehicle with the patrol. The Shift Supervisor then contacts the caller of the emergency job to confirm location, ETA of RACQ Patrol and if the vehicle is in the sun, will also offer the caller suggestions such as covering the vehicle with a blanket or hosing the vehicle down to assist in reducing the temperature of the vehicle.

RACQ patrol staff

All RACQ service providers are trained in a comprehensive package that involves theory and practical components of vehicle entry. The Baby Locked In Car (BLIC) procedure is part of the vehicle entry package.

In the majority of BLIC cases vehicles are entered using conventional methods of vehicle entry. Service providers are also trained in forcing vehicle entry. Forcing entry to the vehicle usually means breaking windows which has significant safety issues associated with the process. Service providers are given guidelines on making the decision whether to force entry and how to break a window safely for the occupant and the service provider (as a last resort).

RACQ has a detailed BLIC procedure which covers the process from beginning to end involving the contact centre, the trainers, the service providers and even the involvement of emergency services, however this procedure is too detailed to show in full in this article. Figure 3 shows the basic order of events in the procedure, from the perspective of the RACQ patrol, from when they are first notified of the call by the call centre.

Occupational safety issues involving staff

When RACQ provides assistance to members and non-members regarding cases where babies, children, adults or animals are locked in a vehicle, a number of important issues must be considered. The call centre staff need to manage the high-stress of the caller, stay calm and coordinate with appropriate RACQ staff.

Because the Club always attempts to send two patrol vehicles to attend such calls, the exposure to risk on the road is increased for that type of call as full details of the situation that they are attending may not be available. Examples of conditions which may be uncertain include the exact location of the locked vehicle (e.g., on road, on shoulder in car park, on driveway etc.) and non-road related environmental factors which may pose a risk e.g., the presence of agitated people and/or animals at the location.

Where two patrol staff are dispatched by RACQ, one patrol staff member works on either entering the vehicle or cooling it down (before emergency service personnel arrive) while the other staff member can manage the caller or bystanders at the site - given their usual anxiety. This is an additional and unique role performed by RACQ patrols for these types of jobs.

Debriefing of staff involved in calls related to BLIC is also an important step conducted by the Club, due to the potential for injury to those who become locked in vehicles.

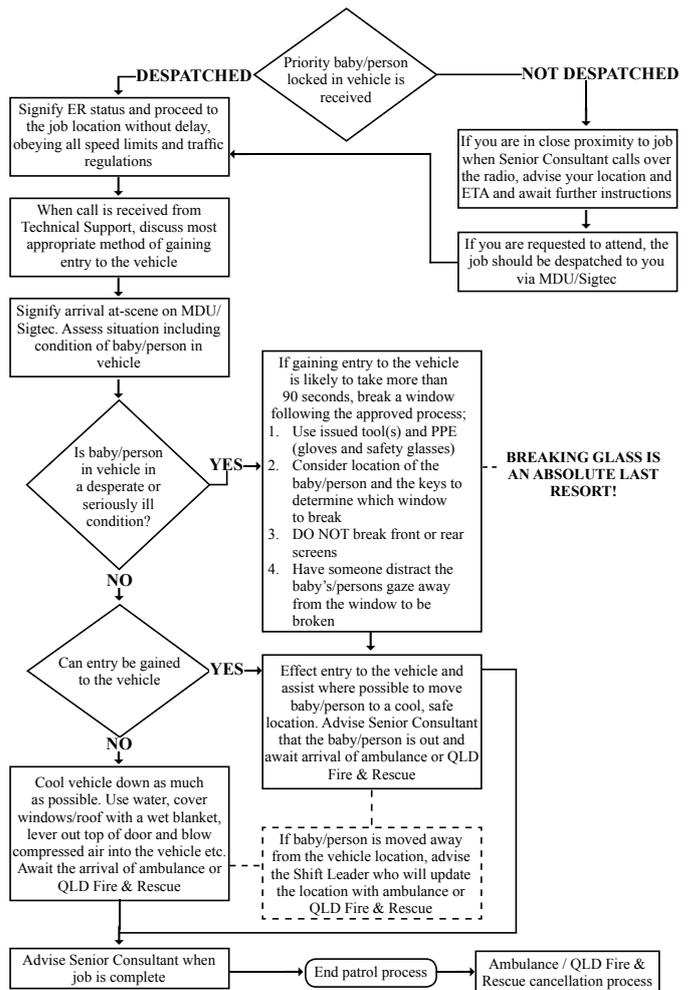


Figure 3: RACQ patrol BLIC procedure flow chart

This process involves additional time and resource costs to RACQ but all steps are necessary to ensure that these high-priority calls are answered and attended as quickly, safely and professionally as possible.

Vehicles are harder to break into

A key concern for RACQ staff involved in answering BLIC calls is that vehicles are becoming more difficult to break into. Manufacturers have improved vehicle safety and security significantly in recent years, resulting in RACQ staff needing to remain at the cutting edge of vehicle security technology, so that BLIC cases can be handled efficiently.

In some cases, due to very advanced security systems, RACQ staff are unable to quickly enter certain makes and models of vehicles and, to avoid negative health effects for the occupant, the step of forcing entry to the vehicle must be taken. Because glass breakage can cause injuries, there is an element of risk in this operation for RACQ staff, the individual locked in the vehicle and bystanders.

Conclusion and RACQ advice for helping to avoid BLIC

The old saying “prevention is better than the cure” certainly applies to BLIC cases and as such RACQ has been very active in providing advice to motorists on ways to help avoid unintentional lock-ins. RACQ advice to motorists includes:

- Always taking the child with you – even if you only intend to leave the car for a brief time.
- Keeping the keys with the driver – never leaving them with the child, in the ignition or placing them on a seat.
- Never let children play with keys or have access to an unattended vehicle.

- Check the vehicle is empty before remote locking – it is easy to make a mistake and accidentally lock them in.

Importantly, if children or adults do become locked in vehicles, the RACQ advises motorists to:

- Keep calm;
- Think clearly and act quickly; and
- Call RACQ (13 1111) immediately for assistance and if there are any concerns about the occupant’s health, call emergency services on 000.

RACQ has also developed a video on lock-ins at: www.youtube.com/racqofficial.

The Club will continue its work in discussing the risks of accidental lock-ins; attending motorists who have children, adults or pets locked in their vehicles; and developing optimal methods to assist as technology changes and vehicle security systems become more complex.

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