Vol 26 No 3, 2015

Journal of the Australasian College of Road Safety

Formerly RoadWise – Australia's First Road Safety Journal

Special Issue: Roads and Infrastructure

Peer-reviewed papers

- From research to practice - development of a rural mass curve treatment program
- Estimating crashes attributable to low and high level speeding: Melbourne compared with Perth and urban Queensland
- Transport-related fatalities and injuries leading to hospitalisation in pre-school children

Contributed articles

- Recent research on safe roads and infrastructure
- Adopting the 3-star minimum safety rating
- Developing a curve risk prediction model for a safe system signature project


NOT DRUNK.
NOT SPEEDING.
JUST TIRED.
One of the 3 big killers on NSW roads.
DON'T TRUST YOUR TIRED SELF
testyourtiredself.com.au
NSW
Transport for NSW

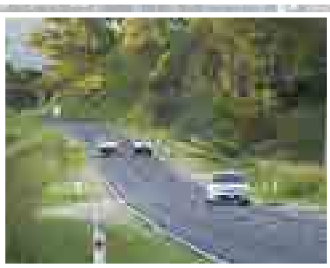
2015
AUSTRALASIAN
ROAD SAFETY
CONFERENCE

Taking action together ...

14-16 October 2015
Gold Coast, Queensland, Australia

Register now!

Don't miss ARSC2015 - the premier road safety conference for Australia, New Zealand and the Asia Pacific region.



ARSC2015 combines the Australasian College of Road Safety (ACRS) Conference, and the Australasian Road Safety Research, Policing and Education Conference (RSRPE) into one event, bringing together over 400 of the region's leading road safety researchers, practitioners, students and policy makers.

With a theme of *Taking Action Together,* the conference will feature a strong program of national and international keynote speakers, and oral, poster and symposia presentations, addressing the road safety issues identified in the United Nations Decade of Action for Road Safety - Road Safety Management, Infrastructure, Safe Vehicles, User Behaviour, and Post-Crash Care – and showcase the latest research, programs and developments in the field.

Who should attend?

ARSC2015 will be an opportunity for all working toward reducing the incidence of road trauma to come together to share knowledge and ideas, and to form networks and new partnerships. The Conference Organising Committee welcomes those from a wide variety of areas including the behavioural sciences, education and training, emergency services, engineering and technology, health and rehabilitation, policing, justice and law enforcement, local, state and federal governments, traffic management and vehicle safety industries.

For more information, to view the conference program, or to register to attend, visit the conference website at **www.australasianroadsafetyconference.com.au**

Inviting parties

AUSTRALASIAN COLLEGE OF ROAD SAFETY

Austroads

CARRS

Platinum Sponsor

Queensland Government

Proudly supported by the Queensland Government

Ambulance image courtesy of Michael Marston, Department of Community Services

3M–ACRS

Diamond Road Safety Award 2015

Keeping people safer through innovative best practice

ENTER & GET RECOGNISED!

Have you or a colleague recently developed a road safety treatment/initiative that stands out beyond traditional activities and delivered improved road safety? You could be the winner! We are looking for entries from **any road safety practitioner** who works within the Australian private or public sector. Don't miss out on your chance to win and be recognised!

WHO WILL JUDGE ENTRIES

All entries will be judged by an independent committee of industry representatives, established by the ACRS specifically for this award.

DIAMOND AWARD

The individual Team Leader from the winning project will **RECEIVE a trip** to the **USA** to attend the **46th ATSSA Annual Convention & Traffic Expo at Virginia, USA** between the 29th January and 2nd February, 2016 **You will also visit 3M head office.** This individual will also present on their winning entry and international trip at the following ACRS Road Safety Conference in 2016.

TO ENTER & MORE INFORMATION, VISIT

theaustralasianroadsafetyawards.com.au

Entries open 1st May 2015 and close 5pm (EST), 1st August 2015.

Contents

Peer-reviewed papers

Contributed articles

Cover image

Safe roads and infrastructure are key components in a Safe System approach to road safety. (Image provided by the Traffic Management Association of Australia). The safety of workers involved in road works is an important issue discussed by the TMAA in this edition of the ACRS Journal.

The Journal of the Australasian College of Road Safety (published as **RoadWise** from 1988-2004) ISSN 1832-9497. Published quarterly by the Australasian College of Road Safety.

Managing Editor:
Laurelle Tunks, ACRS, PO Box 198, Mawson, ACT 2607
Phone +61 (0)2 6290 2509 Fax +61 (0)2 6290 0914
journaleditor@acrs.org.au

Peer-Reviewed Papers Editor: Prof Raphael Grzebieta, Professor of Road Safety, Transport and Road Safety (TARS) Research, UNSW, West Wing, 1st Floor, Old Main Building (K15), University of NSW, Sydney NSW 2052
Phone +61 (0)2 9385 4479 Fax +61 (0)2 9385 6040
r.grzebieta@unsw.edu.au

Road Safety Literature Editor: Andrew Scarce, Road Class, 6 Oasis Gardens, Bendigo, Victoria 3550.
Phone +61 (0)3 5442 5226, Mobile 0429 198 314
Andrew@roadclass.com.au

Subscriptions
All issues of this journal are mailed to personal members or corporate delegates of the Australasian College of Road Safety. Organisations and persons who are not members of the College may subscribe to the journal on payment of an annual subscription.

Advertising and sponsorship
Advertising rates, specifications and deadlines are on the College website at www.acrs.org.au/publications/journaladvertisingkit.html or available by email from faa@acrs.com.au. Discounts are available for prepaid advertising booked to run for more than one issue. The College also welcomes sponsorship of the journal. Our current sponsors are LB International, ANCAP, and New South Wales Government. For more information about becoming a journal sponsor, please contact the Journal Managing Editor.

Editorial Policy
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

The College encourages interested persons and organisations to submit articles, photographs or letters for publication. Published letters would normally show the name of the writer and the state or territory of residence. The journal provides the opportunity for researchers to have their work submitted for peer review, in order to improve the quality of their research papers. However, peer review cannot guarantee the validity of research nor assure scientific quality. The publisher reserves the right to reject submissions or, with approval of the author, to edit articles. No payment is offered for articles published.Material in this journal may be cited with acknowledgement of the full reference, including the author, article title and the year and volume of the journal. For permission to reprint articles, please contact the Journal Managing Editor.

Important Information for authors
It is essential that authors writing for the journal obtain and follow the ***ACRS Instructions for authors***. These are updated regularly and can be downloaded from the College website at www.acrs.org.au/srcfiles/Instructions-for-authors-revised.pdf. **Authors should check that they have complied with all requirements before submitting their papers.** All papers must be in MS Word format and sent as email attachments to *journaleditor.acrs.org.au*. Articles must not exceed 5000 words in length and authors should state whether or not peer review is requested. Authors must indicate if their articles have been published previously or are under consideration by other publishers. The College has adopted guidelines developed by the Committee on Publication Ethics, which are available at http://publicationethics.org/guidelines. These guidelines include the *Code of conduct; Best practice guidelines for journal editors; Guidelines for retracting articles; Guidelines for the board of directors of learned society journals; Guidance for editors: Research, audit and service evaluations;* and *How to handle authorship disputes: A guide for new researchers*.

ACRS office contact details
Submissions to the journal, and any queries or comments about journal content, should be addressed to the Managing Editor. Inquiries regarding journal subscriptions, changes of address and back issues should be addressed to the Finance and Administration Officer.
Inquiries about membership and College activities should be directed to the Executive Officer.

Contacts: Mrs Claire Howe, Executive Officer, eo@acrs.org.au
Ms Laurelle Tunks, Managing Editor, journaleditor@acrs.org.au
Ms Christine Bethwaite, Finance and Administration, faa@acrs.org.au

Mailing address: PO Box 198, Mawson, ACT 2607 Australia
Phone: (02) 6290 2509
Head office: Pearce Centre, Collett Place, Pearce ACT Australia
Office hours: Tuesday 9.00am – 5.00pm; Wednesday and Thursday 9.00am – 3.00pm. Closed Monday and Friday.
Messages may be left on voicemail when the office is unattended.

PRIME MINISTER

A message from the Prime Minister

I am pleased to provide this message for the Australasian College of Road Safety Journal.

Road safety in Australia is improving.Over the last decade road fatalities have decreased by over 25 per cent and in 2014 we had the lowest number of deaths on our roads since 1945.

Better roads, safer cars, compulsory seat belts, random breath testing and better driver training have all helped to save lives.

Sadly, there were still over a thousand people killed on our roads last year and many more were seriously injured.

Though we have made progress, we still must do more to reduce the number of serious injuries and lives lost on our roads.

The Government is doing its part. We are investing a record $50 billion to build roads and infrastructure throughout Australia, including funding for the duplication of the Pacific Highway and to fix the Bruce Highway.

We are spending over $3 billion on the Roads to Recovery Programme as well as $500 million on the Black Spot Programme over the next five years. This will be vital to improving the most dangerous stretches of road across our country.

These projects will make a major difference. But it is up to all of us to accept responsibility for safety on our roads.

I thank the Australasian College of Road Safety for its support and advocacy across all spheres of road safety.

Together we will help further reduce road trauma and save more lives.

The Hon Tony Abbott MP
Prime Minister of Australia

6 July 2015

From the President

Dear ACRS members,

This is another busy edition for you to read. There are many different contributors on a range of road safety subjects.

Importantly we have a supporting message for the College from our Prime Minister, the Honourable Tony Abbott outlining his concern about road trauma and his commitment to significant funding to upgrade roads. He also makes two key points: "It is up to all of us to accept responsibility for safety on our roads" and "Together we will help further reduce road trauma and save more lives". We thank him for his support and look forward to working with his Government to achieve further reductions in road trauma.

Recently at our Annual General Meeting some members suggested we should be more focussed and more specific with our road safety messages.

Our "broad church" approach does not suit everyone. There are always questions in the air about what the College stands for; what are our policies, why do we exist and do we represent our members' views?

As you know as President I have always been keen to encourage collaboration, to bring together the many and varied road user groups, researchers, regulators and practitioners as well as many who often do not realise their involvement in road safety. By working together we should aspire to build a better platform of knowledge and a more efficient action program.

I realise that it has been said we are entitled to our own opinions but not to own facts. However, we do need to test and encourage debate on those facts; recognise that we will have different priorities; and respect the rights of others to put their positions.

Our simple mission is to reduce unnecessary road trauma, in as many ways as possible. We aspire to the vision that no one should die or be seriously injured on the roads.

Our Executive, with your help, is keen work to review what we do so we can achieve that mission.

Lauchlan McIntosh AM FACRS
ACRS President

Diary

8 – 9 September 2015
4th Annual ITS and Road Safety Forum
The Westin Doha
http://www.itsroadsafetyqatar.com/

13 – 16 September 2015
Asia Pacific Cycle Congress
Brisbane, Queensland
http://cyclecongress.com/

6 – 8 October 2015
Road Safety and Simulation International Conference
Orlando Florida, United States
http://stc.utk.edu/STCevents/rss2015/

14 – 16 October 2015
Australasian Road Safety Conference: Taking Action Together
Gold Coast, Queensland
http://australasianroadsafetyconference.com.au/

2 – 5 November 2015
25th World Road Congress
Seoul
http://www.piarcseoul2015.org/wrcs/about/overview

9 – 11 November 2015
4th International Conference on Driver Distraction and Inattention
Sydney
http://wired.ivvy.com/event/DD2015/abstract/request

16 – 18 November 2015
8th International Urban Design Conference
Brisbane, Queensland
http://urbandesignaustralia.com.au/

18 – 19 November 2015
Second Global High Level Conference on Road Safety
Brasilia, DF Brazil
http://www.roadsafetybrazil.com.br/en

25 – 27 November 2015
A12th Australasian Injury Prevention and Safety Promotion Conference
"Impact and Innovation: Preventing Injury in a Changing World"
University of Sydney, Sydney
http://event.icebergevents.com.au/injuryprevention2015

2016
May 2016
Road Safety on Five Continents (RS5C)
Rio de Janeiro, Brazil
http://www.vti.se/en/road-safety-on-five-continents

2 - 5 August
ICTTP2016: The Sixth International Conference on Traffic & Transport Psychology, Brisbane Convention and Exhibition Centre, Queensland, Australia. Website: http://icttp2016.com, Email: icttp2016@qut.edu.au

Other opportunities to enhance road safety?

Prof Mark Stevenson
Professor of Urban Transport and Public Health
The University of Melbourne

As we are now midway through the United Nations Decade of Action for Road Safety it is time for transport agencies, researchers and advocacy groups to consider whether what they are implementing is sufficient to achieve reductions in road trauma. Whilst in Australia deaths from road traffic injury have been declining over the past four decades, the rate of serious road injury is increasing at a rate of 1.6% per annum with 66,000 Australians seriously injured in land-transport crashes each year.

Across many highly urbanised countries, governments are emphasising the need to integrate transport plans (including transport safety) with decisions surrounding land-use. This is not new, but what is being acknowledged is that land-use decisions significantly influence transport options and travel choice. Sprawling residential-only development patterns that dominate most Australian cities limits the ability of children and adults to walk or cycle for their daily travel requirements. Low density housing found in such areas renders public transport cost prohibitive, producing a reliance on private vehicles and increasing exposure to risks associated with traffic speed and volume, vehicle emissions and physical inactivity.

The United Nations General Assembly resolution on global road safety acknowledges the challenges associated with reducing the burden of road injury, as do initiatives such as Sustainable Safety and Vision Zero that aim to reduce or eliminate road traffic injury. This is also in-line with the United Nations Post-2015 Sustainable Development Agenda, particularly in the areas of the global trend towards urbanisation and disaster risk reduction and mitigation. Despite the excellent focus of these efforts, particularly the former in relation to reducing road trauma via innovation in road infrastructure, rarely have they acknowledged the impact of land-use or behaviour and their respective roles in influencing transport options and travel characteristics (travel mode, length of travel etc.).

The opportunities afforded by a greater understanding of the role land-use and urban design play in changing modal choice along with the provision of alternate transport, particularly public transport, should not be overlooked with respect to mitigating road trauma. The Australian Road Assessment Program (AusRAP) points to the considerable and ongoing investment that is needed to extend approximately half of the surveyed highways beyond the current 3-star category rating (1 star is least safe and 5 star the safest road) and, although this investment must continue, understanding how to design and manage the infrastructure to support modal shifts to low risk travel modes needs to be a priority.

The traditional approaches we have applied over much of the past four decades in road safety have delivered well and they ought to continue too; albeit with diminishing returns. Moving forward, there is a need to better understand and quantify the complexity of the transport system and to acknowledge that enhancements to the road infrastructure will be ongoing, particularly as Australian cities become more urbanised and hence, the infrastructure will need to better accommodate modal shifts that are likely to see greater active (walking and cycling) and public transport. Importantly, we will also need to consider the road infrastructure in its broadest context namely, as part of the built environment, if we are going to achieve reductions in serious injuries over the decades ahead.

Safety at roadwork sites crucial to industry

Brendan Woods
Traffic Management Association of Australia (TMAA) President

With government releasing funds for roads and infrastructure projects around the country, the key issue of safety at roadwork sites on such projects raises its head high. In every state, road authorities, road workers, construction, recovery, emergency service and utility providers work in dangerous conditions on roads and sites. Heading up the safety net for these sites are the Traffic Management companies and their traffic controllers, often logistically placed at the precarious entry and exit points to the sites and most at risk.

At any given time, traffic controllers are in high demand, but with the prediction of major projects on roads commencing soon, there will be an ever growing need for highly skilled and trained traffic controllers, to ensure compliance and safety around worksites for all. The need for traffic controllers to work on many and varied projects across the country, has bred an industry working often in dangerous work conditions, highlighted by vehicles and motorists often speeding, reversing or driving dangerously towards and through sites. Devastatingly, many traffic controllers have become fatalities at sites across the nation and not a day goes by where the high risk of ‘near miss’ is not prevalent. Statistics show that many unsafe and near miss work incidents go unrecorded. This means the focus on such safety is often lost in the mix. It is important that the traffic management industry itself raises the bar, not waiting for road authorities to make decisions around compliance or surveillance. Companies all have an obligation to their staff to provide them with the correct training/competencies and safety. It is unacceptable to take best price or take shortcuts at the expense of employees’ safety.

Now, more than ever, it is crucial for all players in the infrastructure, road, utility, emergency, construction and relief services to ensure that their traffic control and site compliance requirements are risk free. Lost time injury causes issues for companies with their premiums and cover claims, but the fatality of a traffic controller or a worker is much more far reaching. It is important that we lobby local, state and federal government to ensure the message of safety at roadworks is not a 'feel good' temporary tag, but an ongoing benchmark for industry. It is an integral part of ensuring all traffic controllers and workers return home safely to their families each day. I congratulate Austroads, who are undertaking the Safety at Roadworks project, along with that of national registration for traffic control companies. These initiatives will go a long way to ensuring traffic controllers and the workers they protect are safe on site and compliant at work.

Head Office News

Welcome to Bronze Corporate members

- Advanced Driver Training Centre - Charters Towers, Brisbane, Melbourne and Canberra;
- Shawsett Training - Bellevue in Perth and;
- Wyong Shire Council - Central Coast, NSW.

Chapter reports

Queensland Chapter

I am pleased to present the 2015 Annual Report on the activities of the Queensland Chapter of the ACRS.

We have held five major seminars. All seminars were well attended and prompted considerable discussion among members and other attendees. I would like to thank all the guest speakers for contributing their time and expertise, including:

March 2014

Rob McInerney, CEO, international Road Assessment Programme (iRAP)

Seminar Topic: *The need for a road safety target in the new Millennium Development Goals*

June 2014

Dr Alexia Lennon, Senior Lecturer, CARRS-Q

Seminar Topic: *Understanding aggressive driving on our roads: where are we and where to next?*

September 2014

Mr Peter Bilton, co-founder and Director of Point8 Pty Ltd, a specialist traffic and transport consulting firm based in Brisbane.

Seminar Topic: *Planning Road Safety: Development of the Gold Coast Road Safety Plan*

December 2014

Dr Ashim Debnath, Post-doctoral Research Fellow, CARRS-Q

Seminar Topic: *Improving safety at roadworks: Understanding the views of workers, motorists and transport professionals*

March 2015

Dr Ray Bingham, Professor, UMTRI

Seminar Topic: *Development and Evaluation of an Evidence-based Parent Coaching Guide for Learner Teen Drivers*

ACRS Queensland Chapter AGM:

The Annual General Meeting was held on 27 May 2015. The following members were elected - Dr Kerry Armstrong (Chair), Dr Mark King (Deputy Chair) and Veronica Baldwin (Secretary/Treasurer). Committee: Professor Narelle Haworth, Joel Tucker, Dr Ioni Lewis, Dr Ashleigh Filtness, Dr Nerida Leal, Lisa-Marie O'Donnell and Dr James Freeman.

I look forward to my last year as Queensland Chapter Chair and hope to provide members with opportunities to meet and discuss current and emerging issues of importance to road safety.

Kerry Armstrong
Queensland Chapter Chair

South Australian ACRS Chapter Report - 2014/15

President's Report

The South Australian chapter continues to provide engagement with road safety stakeholders via its lunchtime dialogues and maintains a regular audience of 30 to 50 people at each dialogue. Annually, the chapter aims to hold six dialogues on a diverse range of topics as a free resource for ACRS members and people working in road safety. In the past year, topics included:

Cannabis and alcohol in road crashes
Dr Matthew Baldock (CASR)
27 June 2014

Crash coding system (DCA)
Emily Cornes (DPTI), Kate Bogan (DPTI), Ross McColl (MAC)
29 August 2014

Trauma systems and damage control surgery
Dr Rob Atkinson, Dr Peter Bautz
19 December 2014

Review of the National Road Safety Strategy
Professor Mary Lydon (CASR),
Dr Jeremy Woolley (CASR)
16 December 2014

Vehicle Technology Update
Matthew Leyson (DPTI),
Dr Jamie Mackenzie (CASR)
17 March 2015

Mad March
Craig Kloeden (CASR)

The ARRB Driverless Vehicle Initiative: Human Factors Challenges and Opportunities
Michael Reagan, ARRB
17 June 2015

The SA Chapter also contributes behind the scenes in several capacities to national College activity and also state based stakeholder group discussions.

I would like to acknowledge the ongoing sponsorship support received from the Motor Accident Commission that allows the lunchtime dialogues to continue as a free resource to ACRS members and the road safety community in general in South Australia. The Department of Planning, Transport and Infrastructure also provide in-kind support by allowing the use of their conference facilities for the lunchtime dialogues.

I would like to thank the committee and in particular Ross McColl for their contributions during the year and encourage others to become involved with the committee and contribute to efforts to reduce the terrible burden of road death and trauma on our community.

Jeremy Woolley
South Australian Chapter Chair

ACT and Region Chapter

Ongoing objectives:

- Support the promotion of road safety in the ACT and surrounding areas.
- Translate into practical activities the research and projects coming out of the NRMA-ACT Road Safety Trust (The Trust) and other research fields.
- Act as an informal mechanism for coordination of other bodies with an interest in delivering road safety outcomes in industry or the community as a whole.
- Organise seminars, workshops, and regional events to showcase and share research and practical activities.
- Advocacy - provide an independent opinion on road safety in the ACT and the surrounding regions and influence community leaders, legislators and industry on road safety issues.

The ACT and Region Chapter of the Australasian College of Road Safety completed another successful year in 2014/15. Seminars included:

1) Live longer Drive Safer

As reported last year, in conjunction with the Council of the Ageing (COTA) and organisers of the 2014 ACT Senior Citizens Week, the Chapter ran two seminars (Woden and Belconnen) for senior drivers. Hopefully COTA will continue these seminars on a regular basis in future.

2) Motorcycle safety – Whose responsibility is it?

This was a joint initiative with MRA ACT held on 22 October 2014. It was very successful and around 50 people attended. The Chapter is very grateful for MRA's cooperation.

The outcomes of the seminar were fed into the community views at the Vulnerable Road User Forum in February 2015.

4) Vulnerable Road User Forum

The Vulnerable Road user Forum was held on 23 February 2015. However, much of the planning occurred in 2014. The Chapter organised the Forum for the ACT Justice and Community Safety Directorate (JACS). A report of the Forum was prepared for the ACT Government and a number of initiatives have been instituted since the Forum.

Translate into practice NRMA-ACT Road Safety Trust research findings

The motorcycle safety seminar called upon a Road Safety Trust report and our submission to the Vulnerable Road User Inquiry drew upon Trust reports.

Advocacy

Reports were released during 2015 on the Vulnerable Road User Inquiry and the ACT Speed Camera Performance Audit entitled ***Speed Cameras in the ACT.*** As reported previously, the Chapter made submissions to both of these inquiries.

Other Activities

1) You don't have to be speeding – to be driving too fast on country roads

The Chapter supported the Yass Valley Council, which is an active member of the Chapter, in running ***You Don't have to be speeding – to be driving too fast on country roads*** campaign launched by the Yass Valley Council prior to Christmas 2014. The campaign was designed to address the problem of speed crashes in the Yass Valley Council region.

The project is a great example of what can be achieved by cooperation. Yass Valley Council participated in the Chapter's May 2013 Seminar, "Trauma on ACT and surrounding NSW roads". The Council then built on studies undertaken by the NRMA-ACT Road Safety Trust on crashes involving ACT drivers in regions outside the Australian Capital Territory. The Trust is assisting in funding the campaign. It has involved cooperation in the region and may be extended to other parts of New South Wales.

2) First Meeting in Regional New South Wales

The Chapter held its first committee meeting in regional New South Wales at the Yass Valley Council Chambers on 11 November 2014. It is hoped to have similar meetings in future at Yass and other regional locations.

3) Presentation to Australian Driver Trainer's Association

On 20 September 2014, the Chapter made a presentation to the Australian Driver Trainers' Association Annual General Meeting in Canberra. The interaction suggested that ADTA state organisations might try to participate in ACRS activities.

NRMA-ACT Road Safety Trust

On 3 December 2014, the ACT Attorney-General Simon Corbell announced that the NRMA-ACT Road Safety Trust would be wound down after new insurers had entered the territory's compulsory third party insurance market.

ACRS both at the national and its ACT Region Chapter level owe the Trust a great deal of gratitude for the support it has given to our voluntary organisations to help place road safety issues before the community, our elected political leaders, and those who have been prepared to take up the challenge of cutting the level of road trauma. The Chapter developed an active mutual relationship with the Trust. We have all benefitted from and are indebted to Professor Don Aitkin and his Trust team.

The ACT Government has indicated that a new ACT Road Safety Fund has been established to ensure the continuation of innovative road safety initiatives in the ACT in a similar way as has been administered by the NRMA ACT Road Safety Trust in the past. The initial round of ACT Road Safety Fund grant applications will open in the first half of next year.

2015 AGM

The Chapter held its AGM on 11 May 2015 and the following office holders were elected:

Executive

Eric Chalmers	President & National Exec Rep
Keith Wheatley	Secretary
Stephen Lake	Treasurer

Members

Eddie Wheeler, Linda Cooke, Geoff Davidson, Melisa Weller, Claire Howe, Laurelle Tunks and Chris Lazzari.

Other news

VicRoads: Travel Happy - share the road

VicRoads have launched a campaign to remind road users that there's a place for everyone on the road and that a little respect goes a long way.

The campaign will be rolled out over four phases from 2015 to 2016. To learn more about *Travel Happy – Share the Road* you can view the motion piece on – travelhappy.vic.gov.au.

With the aim of reducing travel stress, aggression, frustration and a lack of compassion for other road users the campaign focusses on reducing this risky behaviour by building mutual respect for sharing the road.

As part of the program the Travel Happy team will be travelling around Victoria to share tips on how to respect your fellow road users. The team will be recording pledges - capturing how road users can promise to travel safer and happier. For more information go to Facebook or travelhappy.vic.gov.au.

The website includes a Road IQ quiz to find out what kind of driver you are. The Road IQ score can then be shared with friends on Facebook. Check out the website to find new ways to make your stress levels go down and at the same time help road users to travel happy.

2015 Australasian Road Safety Conference (ARSC)

The Australasian College of Road Safety (ACRS), Austroads and Centre for Accident Research and Road Safety - Queensland (CARRS-Q), are inviting participation in the premier road safety conference for Australia, New Zealand and the Asia Pacific region - the inaugural Australasian Road Safety Conference (ARSC2015).

ARSC2015 will be held at the Gold Coast Convention and Exhibition Centre, Queensland, from 14-16 October 2015.

The ARSC2015 conference is the result of a successful merger of Australasia's two premier road safety conferences: the ACRS Conference, and the Australasian Road Safety Research, Policing and Education Conference (RSRPE).

With a theme of "*Taking Action Together*", the conference will span the road safety issues identified in the United Nations Decade of Action for Road Safety: Road Safety Management, Infrastructure, Safe Vehicles, User Behaviour and Post Crash Care. Showcasing the latest research, programs and developments in the field, ARSC2015 will feature a strong program of national and international keynote speakers, oral and poster presentations, workshops and symposia.

The conference is expected to attract over 400 delegates including researchers, practitioners, policy-makers and students working in the fields of behavioural science; education and training; emergency services; engineering and technology; health and rehabilitation; policing, justice and law enforcement; local, state and federal government; traffic management; vehicle safety – and more. Austroads, CARRS-Q and the ACRS look forward to your participation in this important event which aligns with international, Australasian and national road safety efforts and is a significant step forward in Australasia's road safety strategy.

Register before 14 August 2015 to take advantage of the Early Bird Registration Fee.

To receive conference updates go to:
www.australasianroadsafetyconference.com.au

Peer-reviewed papers

From research to practice – development of a rural mass curve treatment program

by Chris Jurewicz[1], Tony Chau[2], Paul Mihailidis[2] and Bill Bui[3].
[1] ARRB Group Ltd, Senior Research Engineer, Safe Systems, 500 Burwood Hwy, Vermont South VIC 3133, Australia, chris.jurewicz@arrb.com.au
[2] Trafficworks, PO Box 417, Ivanhoe VIC 3079
[3] VicRoads, Level 10, 1 Spring Street, Melbourne

This award winning paper was presented at the 2014 Australasian Road Safety Research, Policing and Education Conference, 12 – 14 November, Grand Hyatt Melbourne.

Abstract

Rural road curves provide one of the most challenging features to be negotiated by drivers on high speed rural roads. As a result, many drivers make errors resulting in run-off-road and head-on casualty crashes. It has been estimated that such curve crashes on curves account for 18% of all serious casualty crashes on rural roads in Victoria. In order to address this problem VicRoads funded ARRB to investigate and develop a rural mass curve treatment program.

This paper presents overseas and local research background leading to the development of an engineering model for categorising curves according to their crash risk. The risk model prioritised curves to the right, with greater approach speed, change in speed, narrower pavement and a steeper downhill grade. The paper then describes how this research was used to propose an economically viable $100 million road safety funding program using standardised delineation treatment packages applicable to each curve along a route. Such an approach is expected to provide a consistent level of curve delineation and warning, and thus, condition drivers to better respond to the crash risk of the curves ahead. The program is proposed to be applied on selected rural routes with a history of run-off-road and head-on casualty crashes. It is expected the program will save 28 lives and 315 serious injuries over the treatment life.

Introduction

The task of driving on a curve represents a major increase in the risk of driver error, loss of control and a crash event. This is caused by the centrifugal force due to vehicle's inertia which needs to be constantly countered by side friction and corrective action of the driver. Failure to adjust speed and correct vehicle's direction results in a run-off-road event which is sometimes over-corrected. In some cases, such over-correction events result in head-on crashes with opposing traffic.

In the five-year period of 2009 to 2013, run-off-road and head-on crash types accounted for 38% of all serious casualty crashes (i.e. fatal and serious injury) in Victoria, equally proportioned between urban and rural roads. On the rural roads, 32% of these crashes occurred on curves. Figure 1 shows the breakdown of serious casualty crashes on the Victorian road network by crash type (ROR stands for run-off-road, and HO for head-on).

Overall, run-off-road and head-on crashes on curves accounted for 18% of all serious casualty crashes, and 21% of all fatal crashes, on rural roads in Victoria. For these reasons, reducing the risk of these crash types on rural roads was seen as a strategic direction in reducing serious casualties. There was a keen interest by TAC and VicRoads (The Victorian State Road Authority; future program's developer and administrator) to treat curves in a systematic way across the rural road network using low-cost treatments. It was recognised that strict crash history-based approaches would result in inconsistent application of treatments along rural routes, as most curves have no recent casualty crash history. A risk-based approach was preferred in order to deliver a mass treatment of rural curves.

This paper describes how international research evidence was used to develop an engineering risk model for categorising rural road curves according to their risk of run-off-road and head-on crashes. Each curve along a given route was assigned a low-cost delineation treatment package consistent with its risk category, based on the risk score. Such an approach is expected to provide a consistent level of curve delineation and warning, and thus, condition drivers to better respond to the crash risk of the curves ahead. Using additional road network data, the model was used to prepare a successful business case for a rural curve mass treatment program. The paper then describes development of program guidelines and a curve risk categorising practitioner tool. The tool will be used in preparation of candidate projects for a TAC-funded mass curve treatment program implemented by VicRoads.

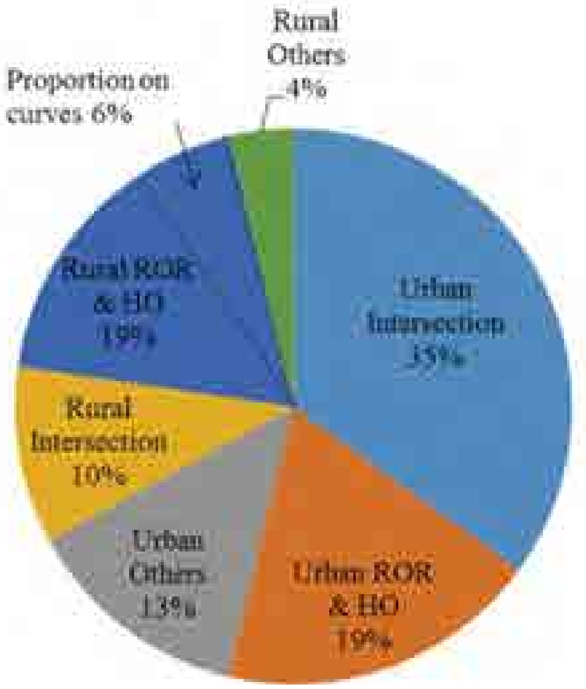


Figure 1. Serious casualty crashes in Victoria (2009 – 2013)

Literature

Herrstedt and Greibe [4] proposed one of the earlier approaches to ranking curves according to risk. This theoretical approach proposed that the change in speed at a curve (difference between approach and design speeds) was the main driver of crash risk. Large change in kinetic energy was proposed to relate to crash severity. They proposed a chart which recognised both the magnitude of speed change and the approach speed. The key innovation of their approach was assignment of five curve risk categories as shown in Figure 2. Each risk category was to be assigned a standardised low-cost delineation treatment package. Herrstedt and Greibe [4] proposed that treatments should be consistent, unambiguous, understandable and easily recognisable. This approach would create driver association between the surprise element (inconsistency), required braking, mental workload and the observed delineation level. It was required that all curves were to be treated along a route to create repetition of the experience.

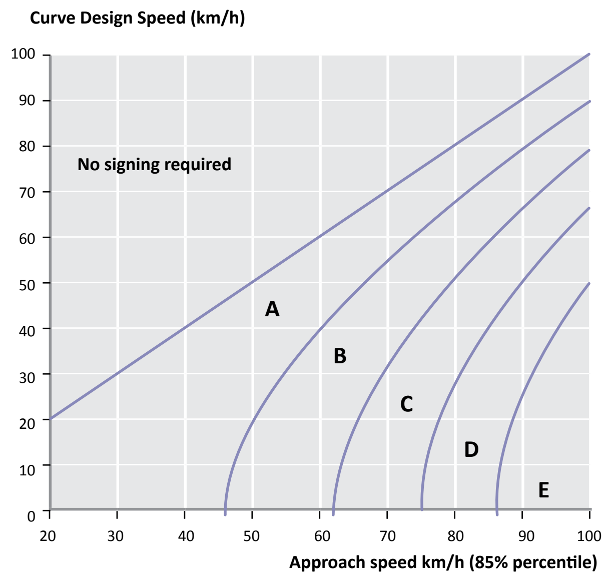


Figure 2. Curve risk categories. Source: Herrstedt and Greibe [4]

The risk categories ranged from low (A) to very high (E). Kirk, Hills and Baguley [7] developed this approach further by designing proposed treatment packages as shown in Figure 3.

Cardoso [2] developed this approach further in Portugal to address the serious problem of curve crashes on rural roads (approx. 31% of all casualty crashes in rural areas). The basic theoretical model was replaced by empirically-developed models for estimating average approach tangent speed, and average speed through the middle part of a curve. These complex equations used factors such as average bendiness (° per km) and average level change (m/km) in the 500m segment preceding the curve, the previous curve radius, pavement width, tangent and curve lengths, and presence/lack of sealed shoulders. These models were in essence similar to operating speed models used in Australia and New Zealand.

The calculated curve and tangent speeds were used in Cardoso's crash prediction models estimating crash rates for curve and approach tangent segments, and the ratio of these (VRAC). Cardoso proposed then that the curve inconsistency factor (FH) should be based on the product of VRAC and the ratio of approach tangent and curve kinetic energies (Equation 1). A higher value indicated a greater inconsistency of the curve with the preceding tangent.

$$FH = VRAC \times \frac{E_c^{tangent}}{E_c^{curve}} \quad (1)$$

where

FH	=	inconsistency factor
$VRAC$	=	ratio of the injury crash rates on curve and tangent
$E_c^{tangent}$	=	kinetic energy at the approach speed (J)
E_c^{curve}	=	kinetic energy at the speed on the curve (J)

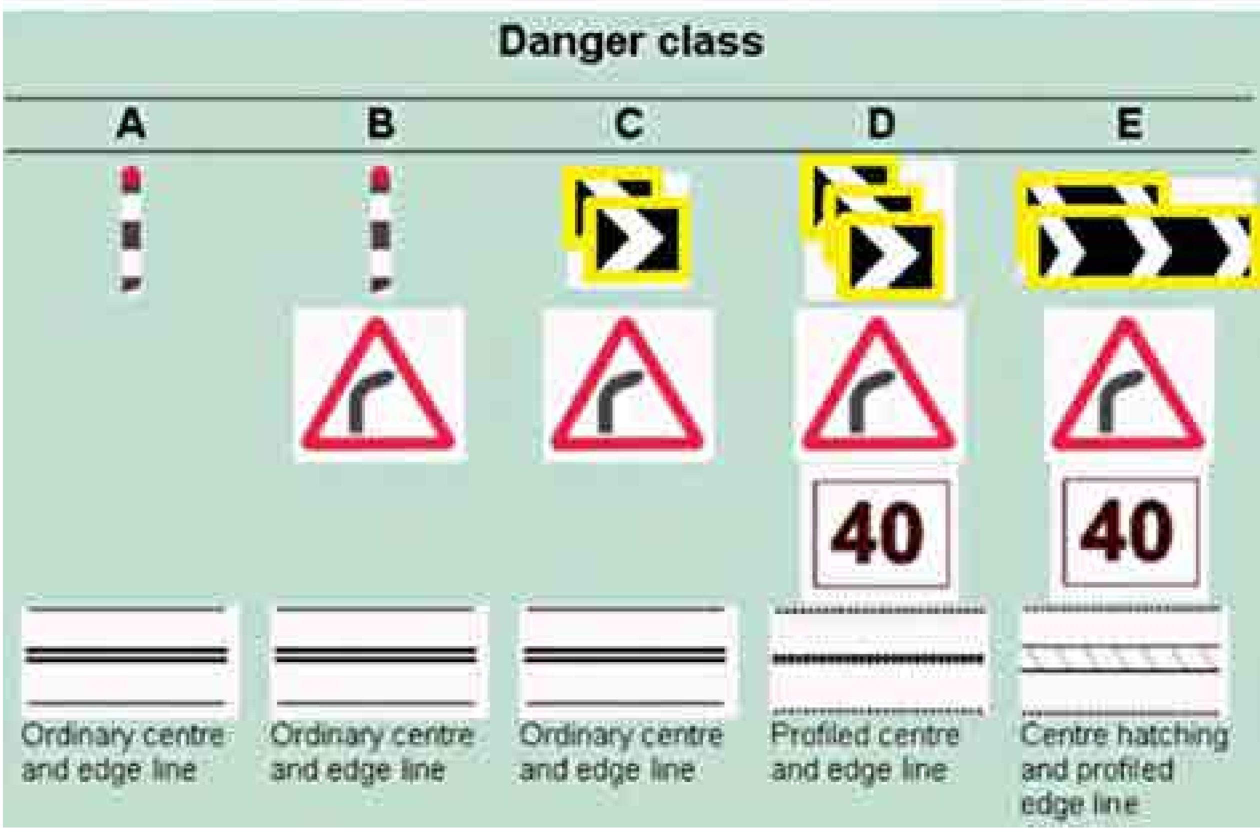


Figure 3. Low-cost treatments for different curve risk categories. Source: Kirk, Hills and Baguley [7]

The major advantage of Cardoso [2] and Herrstedt and Greibe [4] models is that they recognised that both the approach speed and speed change are relevant in the crash risk on curves.

Cardoso developed five curve risk categories based on the inconsistency factor (FH), speed reduction threshold (< or ≥ 5 km/h), deceleration threshold (< or ≥ 2 m/s^2), and presence/absence of sealed shoulders. It appears that approach tangent speed and change in speed were included in the risk categorisation process multiple times. It is not clear why this was seen as appropriate.

As with previous work by Kirk, Hills & Baguley [7], Cardoso [2] proposed five standard treatment packages increasing in delineation and warning sign components as the risk category increased.

Only preliminary, single-year before/after evaluation of the effectiveness of this approach could be identified [3]. The approach, combined with other treatments such as speed limit reduction pavement and drainage treatments, resulted in reported 'risk reduction' of 18% and fatality reduction of 46%. Gomez noted that evaluation could not be completed due to crash data collection difficulties.

Development of the curve risk model

VicRoads sought to develop a curve risk ranking approach with the view to assess all curves on B and C rural routes in Victoria. The B and C routes are the lower order state-controlled rural roads. They carry lower traffic volumes and are typically of a lower design standard than rural highways (A routes). Geometric design inconsistencies were more common, especially on C routes, although isolated curve improvements have been carried out in recent years in response to crash history at individual curves. This added to route-level inconsistency in how the individual risk level of each curve was communicated to a driver. There was a need to develop a curve-specific risk model, and to use it to estimate inputs into a business case for a curve mass treatment road safety program.

Work of Cardoso [2] influenced the approach, although it was agreed that it was overly complex and based on the attributes of the Portuguese road network which may not translate well to Victoria. There was insufficient data available in Victoria to develop similar models. Also, there was a concern that complex models would require inputs requiring costly and time-consuming data collection by practitioners. Such limitations would impede success of a future road safety program. It was agreed to focus on developing an engineering model similar to that proposed by Cardoso [2], but better suited to rapid deployment by VicRoads regional offices.

The critical step in the process was to use research evidence for the key risk factors in curve crashes. These were obtained from reviewing recently published Austroads projects on rural road safety. The initial list of targeted casualty crash risk factors considered were:

- radius of curvature
- curve direction
- clear zone, roadside hazard density, type of hazards
- the overall alignment standard expressed as curves per kilometre
- superelevation
- curve transition – presence, quality
- sealed pavement width
- lane width
- sealed shoulder width
- unsealed shoulder width
- grade
- approach speed
- change in speed at the curve
- AADT.

The quality of the available research evidence for some risk factors was weak (e.g. superelevation). Other factors were well researched, but their influence on crash risk was low (e.g. hazard density). Other risk factors were correlated with each other (e.g. pavement width, sealed shoulder width, lane width and clear zone). After careful consideration, the project team reached consensus to select the following risk factors for the model: curve direction, approach speed and change in speed, sealed pavement width and grade. Traffic flow, AADT, was not included as it describes exposure to risk, rather than the risk itself. It was important to create a model which described the individual driver's risk of curve crash.

The relative risk for curve direction was derived from new analysis of Victorian rural curve data sourced from a recent Austroads project [6]. Table 1 shows that curves leading to the right were relatively more likely to have a run-off-road casualty crash than curves leading to the left. The risks related to differences in crash rates with the risk value of 1.00 being the average crash rate for all curves.

Table 1. Relative run-off-road casualty crash risk on curves of given their direction

Curve direction	Relative risk
Left	0.79
Right	1.21

Cardoso [2] developed crash prediction models to calculate crash rate given approach tangent speed and speed change at the curve. Two variants were developed: in presence of paved and unpaved shoulders. Given that a similar variable, the sealed pavement width, was already included in the model, Cardoso's results were interpolated to account for both shoulder scenarios. The relationship between the relative curve crash risk, average approach speed and average change in speed at the curve is presented as a matrix in Table 2.

Table 2. Relative curve casualty crash risks based on approach speed and speed reduction

		Average speed on the approach tangent (km/h)					
Average change in speed (km/h)		**60**	**70**	**80**	**90**	**100**	**105**
	1	1.00	1.16	1.33	1.49	1.66	1.74
	10	2.12	2.48	2.83	3.19	3.54	3.72
	20	2.67	3.11	3.56	4.00	4.45	4.67
	30	3.05	3.56	4.07	4.57	5.08	5.34
	40	3.35	3.91	4.47	5.03	5.59	5.87
	50		4.21	4.81	5.41	6.01	6.31
	60			5.14	5.75	6.38	6.70
	70				6.04	6.72	7.05
	80					7.02	7.37
	90						7.66

Source: adapted from Cardoso [2]

The analysis of this design feature relating to Victorian rural undivided road data and run-off-road casualty crashes was reported in Jurewicz and Pyta [6]. The relationship is shown in Table 3.

Table 3. Relative run-off-road casualty crash risks for various sealed pavement widths

Pavement width (m)	Relative crash risk
< 6	2.70
6–7	1.69
7–8	1.57
8–9	1.13
9–10	1.00

Source: Jurewicz and Pyta [6]

Similarly, Jurewicz and Pyta provided the relative risk values for the effect of road grade, based on run-off-road casualty crashes and on the same sample of Victorian rural undivided roads.

Table 4. Relative run-off-road casualty risks of positive and negative grades

Grade (%)	Run-off-road relative crash risk
> 6	2.60
4 to 6	1.80
2 to 4	1.40
0 to 2	1.00
0 to -2	1.20
-2 to -4	2.00
-4 to -6	3.40
< -6	5.60

Source: Jurewicz and Pyta [6]

At first a simple multiplicative model was created and applied to all curves of radius less than 600 m on a 400 km sample of rural Victorian B and C roads (200 km of each type). (Jurewicz and Pyta [6] showed that risk of a run-off-road casualty crash was not significantly elevated for curves with radius greater than 600 m). Using an assumption that risk score should have a normal distribution, the model was iteratively refined by adjusting its form and weighting factors. It was expected that the majority of curves across the network should have low to moderate risk score, a significant minority should be moderate and a small minority be of high risk. The final form of the model was as shown in Equation 2.

$$\text{Curve risk score} = RR_{dir}[(0.6 \times RR_{\Delta approach\ speed} \times RR_{pavement\ width}) + (0.4 \times RR_{grade})] \quad 2$$

where:

RR_{dir} = relative risk of the curve direction (right, left)
$RR_{\Delta approach\ speed}$ = relative risk of the change in approach speed, including its original value
$RR_{pavement\ width}$ = relative risk of the pavement width
RR_{grade} = relative risk of the road grade

The application of the model produced the following distributions of the risk scores shown in Figures 4 and 5.

Figure 4. Curve risk scores for C roads

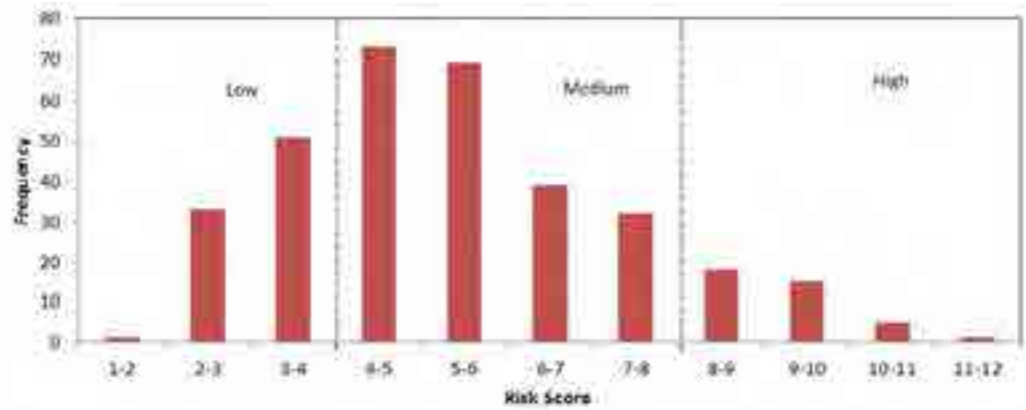
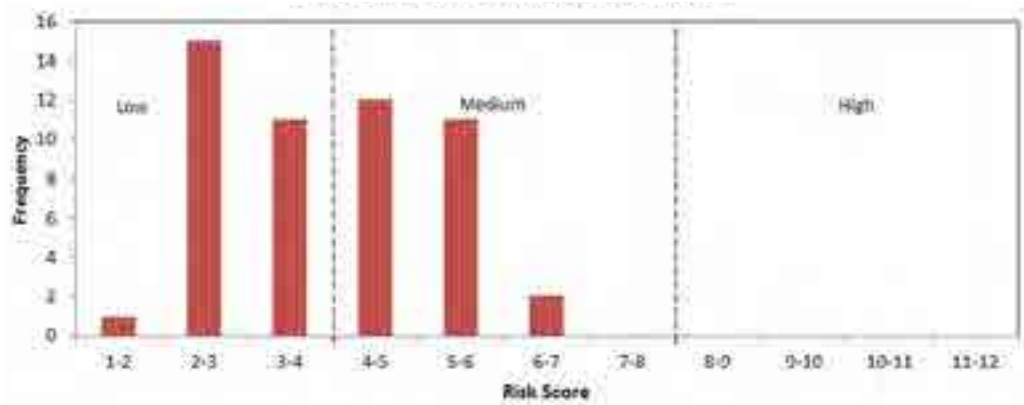


Figure 5. Curve risk scores for B roads



Risk rating of curves on B and C roads confirmed the assumption, although B roads had significantly fewer curves given the same length, and the curves were of lower risk. This confirmed the overall higher design standard of B roads.

To simplify the European approach, only three risk categories were created: low, medium and high, as shown in Figures 4, 5 and 6. Visual sense-checking was applied to a selection of scored curves to confirm the model and risk categories produced results credible to drivers, i.e. high-risk curves were significantly more inconsistent with the approach tangent, than low-risk curves.

Figure 6. High, medium and low-risk category curves

This division into three risk categories allowed the introduction of a consistent treatment package for each category. The treatments were sourced from the VicRoads signs and linemarking guidelines and vetted by VicRoads engineers. The treatments were generally somewhat more generous than the guidelines. Many were made dependant on site conditions, mainly the pavement width along the route.

Low-risk curves received minimal treatment consistent with the approach tangent. Medium-risk category received the same plus additional warning devices. High-risk curves were to be equipped with same as medium plus Chevron Alignment Markers (CAMs) and advisory speed signs.

Additionally, the worst of the high-risk curves will be also eligible for additional treatments such as hazard removal, pavement widening and safety barrier installation. This level of treatment could only be recommended by regional engineers on case-by-case basis, following site inspections, where additional risk factors were present that were not accounted for by the model (e.g. a high roadside drop-off, an intersection, or high number of serious casualty crashes). However, the need to achieve a competitive BCR for each route will place constraints on the type and the extent of these additional treatments.

Each treatment package had an associated crash reduction factor (CRF) estimated from the combination of treatment CRFs, as shown in Table 5.

Table 5. Proposed treatment packages for each curve risk category, with estimated CRFs

Curve type	Treatments	Combined CRF
Low risk	1) Guideposts 2) Edge line (only if pavement width allows) 3) Centreline (only if pavement width allows)	22%
Medium risk	4) RRPM (only if linemarking exists or is possible) 5) Audio-tactile (only if pavement width allows) 6) Curve warning signs for isolated or group of curves	51%
High risk	7) CAMs 8) Advisory speed signs 9) Pavement widening, hazard removal, safety barriers (site-conditional)	57%

As an economic modelling exercise, the correct treatment was hypothetically applied to each risk scored curve in the 400 km road sample. Where curve run-off-road and head-on casualty crashes were recorded in the previous five years, the relevant treatment CRF was applied (only some curves had past crashes). Thus crash savings could be calculated separately for B and C routes. Similarly, treatment costs were estimated using recent historical unit cost rates provided by VicRoads. This approach allowed approximation of risk category and treatment package distribution on B and C routes and of the expected program BCRs for each road category.

Rural mass curve treatment program development

The economic exercise was sufficiently encouraging to extend it into a network-level economic model of program benefits and costs. A proposal was developed and submitted for TAC consideration. TAC approved a $100 million sub-program under the $1 billion Safe System Roads Infrastructure Program (SSRIP) funded by the TAC, to address these prominent crash types on curves of B and C rural roads.

The program is to be applied on all B routes and on the worst performing 6% of C routes, which have 35% of curve run-off-road and head-on serious casualty crashes. The selection of candidate routes for consideration in this program is based on the historic number of serious casualty run-off-road and head-on crashes which occurred on curves of the whole route. This approach ensures only routes with the highest collective risks are included and the highest return from investment can be achieved (ranked by BCR and dollars per serious casualty saved). While only 6% of C routes are proposed to be treated, the high number of curves on this part network demands the greatest expenditure. Treatments in Table 5 will be applied according to risk rating of each curve on the selected routes and local engineering input.

The expected program-level crash reduction factor of 33% is expected, with 28 lives and 315 serious injuries saved over the 15-year life of the treatments. The program is expected to deliver a BCR of 3.7, or the cost of $116,618 per each serious casualty saved.

Program guidelines and curve risk rating tool

Program guidelines were developed to assist regional road safety engineers in preparation of candidate projects. VicRoads used its crash database to rank B and C routes based on curve run-off-road and head-on crash history per kilometre in the latest five-year period. Top routes were prioritised for further assessment by regional engineers in the first year of the program.

The risk model was converted into a practitioner tool in Microsoft Excel to enable rapid risk assessment of all curves along any selected route using Gipsi-Trac data as a source. (GipsiTrac provides a set of geometric road attributes with GPS coordinates at 10m intervals for the entire state road network. Calibrated digital video is also available enabling measurement of other attributes such as widths and lengths). Gipsi-Trac calculates instantaneous traffic speed which was used by the tool to estimate average approach and curve speeds. The speed profile along the road was calculated within the tool using acceleration rates

Curve No	Pavement Width (m)	Risk Score (Fwd)	Risk Score (Rev)	Ranking (Fwd)	Ranking (Rev)	User Defined Ranking (Fwd)	User Defined Ranking (Rev)	Comments
10	6.4	3.66	2.55	LOW	LOW			
11	6.4	1.81	2.44	LOW	LOW			
12	6.4	1.91	1.71	LOW	LOW			
13	6.4	1.81	3.10	LOW	LOW			
14	6.4	3.58	5.39	LOW	MEDIUM			
15	6.4	1.18	1.71	LOW	LOW			
16	6.4	4.45	2.83	MEDIUM	LOW			
17	6.4	5.29	4.98	MEDIUM	MEDIUM			

Figure 7. Aspects of the curve risk rating tool

for straights sourced from Austroads [1] and the speed limit as an upper limit. Gipsi-Trac also produces grade information which was used by the tool to calculate average grade through the curve. This allowed practitioners to focus on driving each route, checking the appropriateness of estimated approach and curve speeds, and measuring the sealed pavement width. Other data may also be entered into the spreadsheet by practitioners such as curve crash records, risk category override and any additional comments to justify it (e.g. additional risk factors). Figure 7 shows different aspects of the tool. For example, curves' different directional categorisation, depending on curve direction and grade. Also, the tool provides an easy mapping export option to Google Earth.

Once all curves on a given route are assessed, engineers estimate the cost of works, obtain relevant crash details from the database, and use the VicRoads tool for estimating the project BCR. All candidate projects in this program which are above the funding BCR threshold nominated by TAC are to be funded.

Discussion

A crash-predictive statistical model based on the target crash group and B and C road network data would be a preferred tool for risk-rating curves. The modelling process would identify the statistically significant factors and quantify their influence on crash risk. The reason why an engineering risk model was chosen instead was that there was insufficient data available to create a viable statistical model. Modelling multiple independent variables using zero-inflated road segment and crash data relies on very large data sets (most curves have no crash history). Crash modelling experience gained during recent Austroads projects using the low-volume Victorian rural road data suggested that a sample of several thousand kilometres or B and C curve segments would be required [6, 5]. Such data sets were simply not available in Victoria, given that curves constituted only 10% of the targeted network.

The engineering risk model based on literature findings offered a more efficient way of building a model. The subsequent sense-checking on-site provided further confidence that curve crash risk categories were assigned accurately. Addition of further flexibilities in the program guidelines (e.g. case-by-case assignment of safety barrier and shoulder treatments) provided further assurance that risk factors excluded from the model would be considered.

Still, the engineering model presents certain limitations. For example, the role of superelevation could not be accounted as evaluation of this risk factor was not well documented in published literature. This aspect should be investigated further, as pavement superelevation at curves is a common treatment for run-off-road crashes.

One limitation of the overall approach is that the model and the funding program recommend mainly delineation treatments. They do not seek to address en-masse other underlying causes of curve crashes that may require more substantive works, e.g. realignment, or pavement rehabilitation. Feedback from regional engineers during development of the funding program guidelines suggested that pavement regulation problems, potholes and poor skid resistance were increasing risk factors behind curve crashes. On some routes, recreational motorcycling was also a key driver of curve crash risk. These factors may need to be accounted for by regional engineers and fed back to VicRoads for consideration in future asset management budgets on B and C roads. Future risk models should consider inclusion of such factors where data permits it.

Conclusions

This paper showed how overseas and local research evidence was combined to develop an engineering crash risk assessment model for ranking of curves. A funding program and project development guidelines were developed to assign standardised delineation treatment packages according to each curve's risk category. Such an approach will provide a consistent level of curve delineation and warning along selected routes, and thus, condition drivers to better respond to the crash risk of the curves ahead.

The risk model was used to secure funding for a $100 million rural curve mass treatment program to be rolled out across Victorian B and C roads over ten years. A practitioner tool was developed to deliver rapid ranking of curves on prioritised routes. Estimated benefits included savings of 28 lives and 315 serious injuries over the life of the treatments.

References

1. Austroads. Guide to Road Design – Part 3: Geometric Design (AGRD03/10). Sydney, NSW: Austroads, 2010.
2. Cardoso, J. Safety assessment for design and redesign of horizontal curves. International symposium on highway geometric design, 3rd, Chicago, Illinois, 2005, 20pp.
3. Gomez, S.V. Low-cost engineering measures for casualty reduction. Application on the national road network. European Conference of Transport Research Institutes, 2005. Retrieved from http://www.ectri.org/YRS05/Papiers/Session-2bis/vieira.pdf
4. Herrstedt, L. and Greibe, P. Safer signing and marking of horizontal curves on rural roads, Traffic Engineering and Control, vol. 42, no. 3, 2001, pp. 82-87.
5. Jurewicz, C., Lim, A., McLean, J. and Phillips, C. Improving roadside safety – stage 3: interim report (AP-R419/12). Sydney, NSW: Austroads, 2012.
6. Jurewicz, C. and Pyta, V. Improving roadside safety – stage 2: interim report (AP-R387/11). Sydney, NSW: Austroads, 2011.
7. Kirk, S., Hills, B., Baguley, C. CASE highway design note 2/01: horizontal curves. London, UK: Department for International Development, 2002.

Estimating crashes attributable to low and high level speeding: Melbourne compared with Perth and urban Queensland

by Max Cameron
Monash University Accident Research Centre, Monash University, Melbourne, max.cameron@monash.edu

Abstract

Relationships linking travel speeds with the risk of casualty crashes have been combined with on-road speed surveys to estimate the proportion of crashes associated with each speed range and potentially attributable to speeding at different levels. This paper used speeds recorded by mobile speed cameras operated covertly in Melbourne 60 km/h speed limit zones. A 1% sample of mobile camera sessions was used to provide estimates of the proportion of casualty crashes attributable to low and high level speeding, using analysis methods similar to those used previously to analyse large speed surveys in Perth and urban Queensland. The analysis compared the results from functions linking casualty crash risk with absolute speed or with the difference between travel speed and the mean speed (mean-centred speed). The effect of different caps on the magnitude of the risk at high speeds was also examined.

The study concluded that a low cap placed on the risk functions is not justified; however analysis using higher caps should make use of the 95% confidence limits on the risk estimate. A rescaled version of the mean-centred speed risk function, referenced to the risk at the speed limit, provides similar results to the risk function based on the absolute speed in 60 km/h limit zones. Rescaled mean-centred speed risk functions could be applied with some confidence to estimate the casualty crash risk, relative to that at the speed limit, at speeds in other urban and rural speed limit zones. From the empirical results, it was also concluded that the pattern of speeding and its contribution to casualty crashes in Melbourne 60 km/h limit zones was very different from that in 60 km/h zones in Perth and urban Queensland.

Background

Analysis of free speeds in Perth and Queensland 60 km/h zones

The availability of two large representative surveys of travel speeds in Western Australia and Queensland during 2010 had allowed previous analysis to be carried out by the author on the contribution of different speed ranges to casualty crashes [1]. The analysis made use of Kloeden et al's [2] relationship connecting the relative risk (RR) of a casualty crash with the free speed (v) of individual vehicles travelling in 60 km/h speed limit zones:

$$RR_1(v) = \exp(-0.822957835 - 0.083680149*v + 0.001623269*v^2) \quad (1)$$

The method followed previous research that had weighted speed observations by their relative risk [3-6], except that it followed Holman's [7] approach and estimated the "population attributable risk" fraction (PARF) for each speed range. PARF is the fraction of casualty crashes attributable to the <u>increase</u> in risk due to the speeding. Other researchers had estimated the relative number of casualty crashes <u>associated</u> with each speed range, but these crashes are <u>not all attributable</u> to the illegal speeds. The concept of population attributable risk associated with crash risk factors is outlined by Elvik [8]. Its calculation for each level of a polytomous risk factor (e.g., speed range) is defined by Walter [9].

Table 1 presents ranges of illegal speeds observed in 60 km/h zones in Perth and Queensland during 2010, together with the estimated fraction of casualty crashes attributable to speeding in each range. In these jurisdictions, it is estimated that 24% to 33% of casualty crashes were attributable to high level speeding (more than 20 km/h above the limit) and 12% to 16% were attributable to low level speeding (up to 10 km/h above the limit).

Table 1: Attributable fraction of casualty crashes due to speeds on 60 km/h speed zone roads in Perth and Queensland during 2010

	Perth 60 km/h limit zones			**Queensland 60 km/h limit zones**		
Speed range (km/h)	Speeds observed (N = 664,414)	Percent of speeds observed	Attributable fraction of casualty crashes	Speeds observed (N = 2,532,322)	Percent of speeds observed	Attributable fraction of casualty crashes
60-65	175,230	26.37%	4.8%	607,980	24.01%	4.0%
65-70	88,133	13.26%	10.9%	276,663	10.93%	8.3%
70-75	31,134	4.69%	10.6%	105,896	4.18%	8.7%
75-80	9,846	1.48%	8.4%	41,114	1.62%	8.5%
80-90	4,343	0.65%	15.4%	23,595	0.93%	20.3%
90+	892	0.13%	8.7%	5,233	0.21%	12.4%

Analysis of mobile camera detected speeds in Melbourne 60 km/h zones

Alavi, Keleher and Nieuwesteeg [10] analysed a 1% sample of mobile speed camera sessions conducted in Victoria during 2013, including those in 60 km/h limit zones in Melbourne. Sessions sampled were limited to those with traffic volumes within one standard deviation from the mean traffic volume from all sessions at each site, in order to avoid the effect of dense or sparse traffic on the speeds recorded. The mobile speed cameras are operated covertly and are relatively invisible and unpredictable in urban areas. A total of 105,101 speed observations were recorded, excluding an inflated number of records at the offence detection threshold because this speed is used for test shots of the speed camera before and after each session. An estimate was made of the true number of actual speeds at the threshold (450).

Alavi et al [10] weighted each detected speed by the relative risk of a casualty crash, making use of Kloeden et al's [2] second relationship connecting risk with the difference (D) between free speed (v) and the mean speed (m) at crash locations in urban areas:

$$RR_2(v) = \exp(-0.1133374*D + 0.00281717*D^2) \quad (2)$$

where D = (v – m). The mean speed detected in the sampled sessions in 60 km/h limit zones in Melbourne during 2013 was 52.7 km/h. For various reasons, Alavi et al [10] capped the relative risk function (2) at that corresponding to 21 km/h above the mean speed, i.e. 74 km/h with relative risk of 37. They then interpreted the risk-weighted detected speeds as [proportional to] the expected casualty crashes associated with each speed and potentially attributable to it. Because their focus was on illegal speeds above the limit, they summed the illegal risk-weighted speeds and calculated the percentage of expected crashes in each speeding range (Table 2). It can be seen that these percentages differ substantially from the distributions of attributable fractions of crashes due to speeding in 60 km/h limit zones in Perth and Queensland (Table 1).

Table 2: Estimated distribution of expected casualty crashes associated with speeding across each illegal speed range, Melbourne 2013

Speed range (km/h)	Speeds detected (N = 105,551)*	Percent of speeds detected	Expected casualty crashes (sum of individual speeds by relative risk)	Percent of casualty crashes associated with illegal speeds
61-65	7,955	7.54%	32,534.3	46.6%
66-70	1,827	1.73%	18,889.2	27.1%
71-75	423	0.40%	11,698.7	16.8%
76-80	109	0.10%	4,033.0	5.8%
81+	71	0.07%	2,627.0	3.8%

**Includes 450 estimated detections at the offence detection threshold, hence percentages differ slightly from Alavi et al [10] Tables 3 and 5*

VicRoads surveys of trends in mean speeds in Melbourne

VicRoads has conducted bi-annual surveys of free speeds at sites in Melbourne since 1994. In each site-direction, 100 speed observations are recorded on weekdays during 10am to 12pm and 1pm to 3pm. Speeds are recorded only for vehicles with a headway of at least four seconds to ensure their speed is unimpeded (free). During May 2013, observations were made at 13 sample sites in each direction in 60 km/h limit zones. Thus it was estimated that 2,600 speed observations were collected.

The estimated mean speed at 60 km/h limit sites in Melbourne during May 2013 was 58.9 km/h [11]. This is about 6 km/h higher than the mean speed estimated from covert mobile speed camera detected speeds in Melbourne 60 km/h limit zones during the whole of 2013 [10]. It is not known which of these two sources provides a better estimate of mean speeds in that road environment. However it is possible that the VicRoads samples taken on weekdays during off-peak periods could be biased in the direction of higher speeds. In addition, the relatively small VicRoads sample (2,600) may not provide a reliable estimate of mean speed compared to the larger sample of mobile speed camera sessions (105,551 speed observations).

Research questions

The different pattern of results in Tables 1 and 2 has led to the following research questions.

1. What is the influence of the different analysis methods, in particular the following specific differences (Table 1 versus Table 2, respectively):
    a. Population attributable risk fraction versus risk-weighted speeds
    b. Relative risk function of absolute speed versus the function of difference from mean speed
    c. Capping the risk function at 90 km/h versus 74 km/h
    d. Based on speed frequencies in 5 km/h wide ranges versus individual speeds?
2. Are casualty crashes attributable to each range of speeding substantially different in Melbourne's 60 km/h limit zones compared with those in Perth and Queensland, perhaps reflecting the influence of Victoria's different operation of mobile speed cameras (covert versus overt) and other speeding-related initiatives?

Item 1(d) of these research questions will be addressed first by analysing the speeds detected at the 1% sample of covert mobile speed camera sessions in Melbourne 60 km/h zones in the same way as analysed by Cameron [1]. This will allow a direct comparison with the results from Perth and Queensland. Subsequent analysis will examine questions 1(a)-(c), but based on the richer data from Alavi et al [10] providing frequencies of individual speeds.

Research question 2 will be addressed following the results of analysis addressing question 1. While any conclusions may be tempered by the assumptions, the pattern and magnitude of the differences between the three States' urban speeds may be indicative.

Assumptions

It was assumed that the speeds detected by covert mobile speed cameras in urban Melbourne represent a reasonable proxy for free speeds measured in substantial and representative speed surveys. Although a VicRoads survey in May 2013 has suggested a mean free speed about 6 km/h higher than the camera-detected mean speed in Melbourne

60 km/h limit zones, the limited times of week, number of sites and observations, and season of the year used in the VicRoads survey does not provide conclusive evidence that the camera-detected speeds are not representative.

It was further assumed that the relative risk functions (1) and (2) developed by Kloeden et al [2] provide indicative estimates of increases and decreases in casualty crash risk, within the confidence limits given in Tables 2.2 and 2.3 of their report [2].

Analysis of Melbourne speed ranges

Cameron [1] analysed speed survey data from Perth and urban Queensland using Kloeden et al's [2] relative risk function and its 95% confidence limits, which were tabled for speeds ranging from 45 to 90 km/h [2, Table 2.2].

Natural logarithms of the function and limits are shown in Figure 1, together with quadratic functions fitted to the tabled values. This functional form reflects equation (1) when natural logarithms are taken of the relative risk.

In the same way as Cameron [1], the relative risk function and limits were applied to the mobile speed camera-detected speeds after classifying the speeds into the ranges shown (Table 3). The speed ranges differ somewhat from Cameron [1], so the mid-mark speed used to estimate each relative risk and limits also differ. In particular, 93 km/h with an estimated relative risk of 229.2 was used as the reference speed for the 91+ km/h speed range.

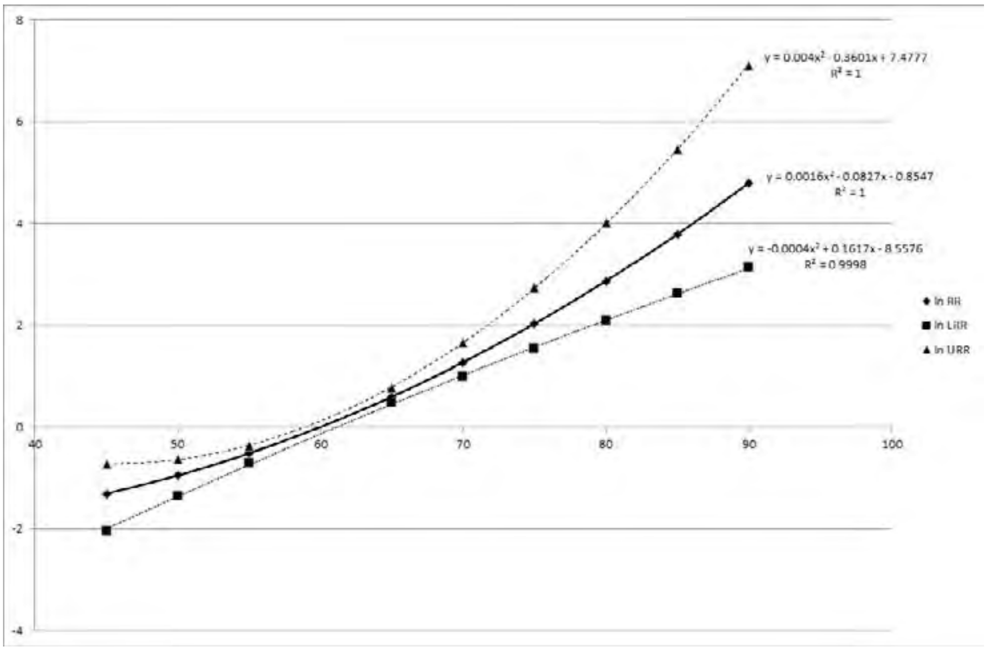


Figure 1: Natural logarithms of Kloeden et al's [2] relative risks (RR) and upper (URR) and lower (LRR) confidence limits versus travel speed in 60 km/h limit zones

Table 3: Attributable fraction of casualty crashes due to speeds detected on 60 km/h speed zone roads in Melbourne, 2013

				Contribution to speed attributable fraction: p*(RR – 1)			**Estimated population attributable risk (PAR) fraction of casualty crashes**		
Speed range (km/h)	Count of speeds detected in 2013 (N = 105,551)	Percent of speeds detected (p*100)	Estimated relative risk of casualty crash (RR)	Based on relative risk (RR)	Based on lower limit of relative risk (LRR)	Based on upper limit of relative risk (URR)	Attribut-able fraction (%)	Lower attribut-able fraction (%)	Upper attribut-able fraction (%)
1-30	477	0.45%	0.150	-0.0038	-0.0045	0.0078	-0.6%	-0.7%	1.1%
31-40	3,342	3.17%	0.183	-0.0259	-0.0302	-0.0107	-3.8%	-4.4%	-1.6%
41-45	8,873	8.41%	0.242	-0.0637	-0.0753	-0.0419	-9.3%	-11.0%	-6.1%
46-50	22,532	21.35%	0.333	-0.1424	-0.1705	-0.1075	-20.7%	-24.8%	-15.6%
51-55	35,025	33.18%	0.497	-0.1668	-0.2056	-0.1324	-24.3%	-29.9%	-19.3%
56-60	24,917	23.61%	0.806	-0.0458	-0.0698	-0.0262	-6.7%	-10.2%	-3.8%
61-65	7,955	7.54%	1.416	0.0314	0.0209	0.0458	4.6%	3.0%	6.7%
66-70	1,827	1.73%	2.699	0.0294	0.0220	0.0442	4.3%	3.2%	6.4%
71-75	423	0.40%	5.578	0.0183	0.0118	0.0344	2.7%	1.7%	5.0%
76-80	109	0.10%	12.503	0.0119	0.0059	0.0316	1.7%	0.9%	4.6%
81-90	58	0.05%	30.395	0.0162	0.0056	0.0695	2.4%	0.8%	10.1%
91+	13	0.01%	229.165	0.0281	0.0035	0.4662	4.1%	0.5%	67.9%

Table 3 indicates that 8.9% of casualty crashes are attributable to low-level speeding in the 61-70 km/h range and 6.5% of crashes are attributable to high-level speeding more than 20 km/h above the 60 km/h limit. This compares with the analysis of 60 km/h limit zone speeds in Perth and Queensland, where 24% to 33% of casualty crashes were attributable to high level speeding and 12% to 16% were attributable to low level speeding (Table 1).

Table 3 also indicates that there was a substantial contribution to preventing casualty crashes due to many vehicles travelling well below the speed limit in 60 km/h zones in Melbourne. The largest negative attributable fractions suggest that 21% of casualty crashes expected, if all vehicles were driven at 60 km/h, were saved by those driving at 46-50 km/h, and a further 24% of crashes were saved by those driving at 51-55 km/h.

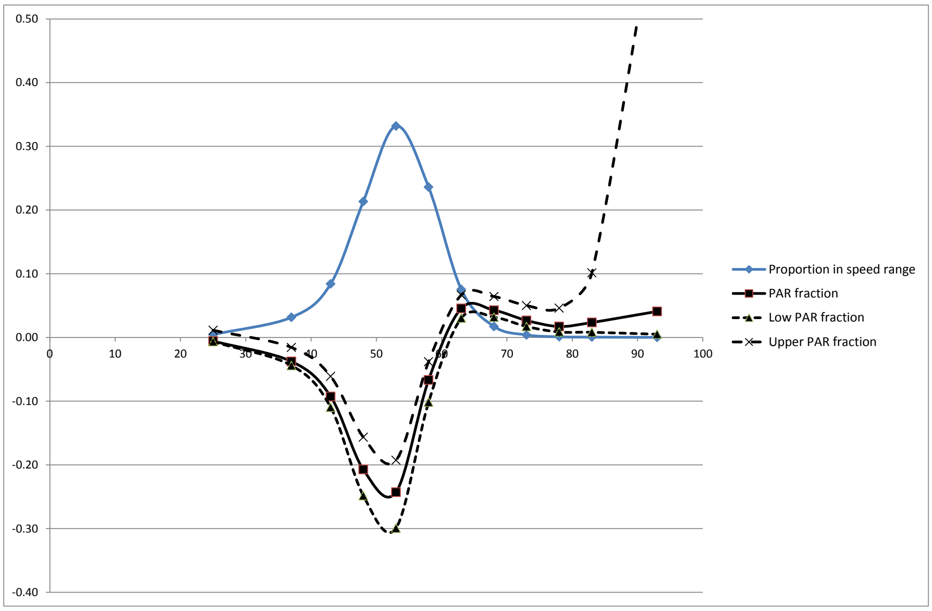


Figure 2: Estimated attributable fraction of casualty crashes for each speed range in Melbourne 60 km/h zones during 2013

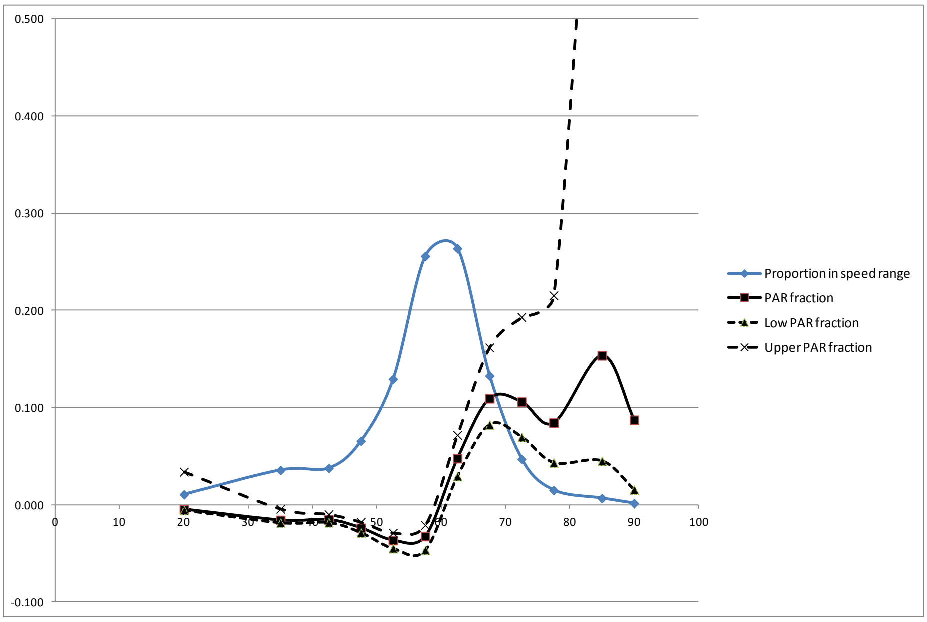


Figure 3: Estimated attributable fraction of casualty crashes for each speed range in Perth 60 km/h zones during 2010

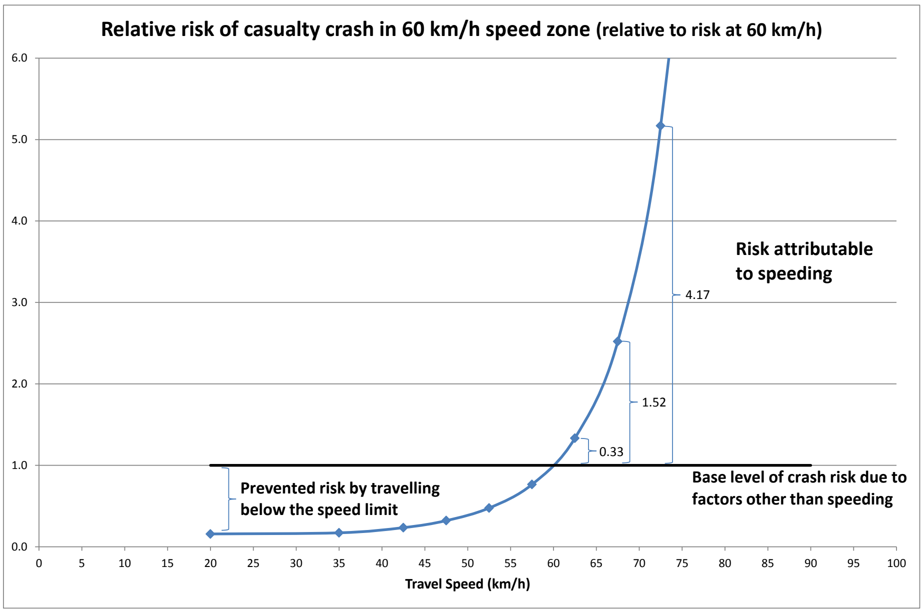


Figure 4: Kloeden et al's [2] relative risk function, showing the component of risk attributable to speeding and the risk prevented by travelling below the speed limit

These contributions to preventing casualty crashes in Melbourne, together with confidence limits on the population attributable risk (PAR) fraction of crashes saved, are shown in Figure 2. This compares favourably with the situation in 60 km/h limit zones in Perth, where vehicles driven below the limit contributed less than 4% savings in any legal speed range (Figure 3). As noted above, vehicles being driven above the 60 km/h limit in Perth appear to contribute substantially to casualty crashes, especially at high-level illegal speeds. The situation appears to have been even less favourable in urban Queensland, as shown in Cameron's [1] Figure 8 (not presented here).

The contribution of speeds below the limit in reducing relative risk, and hence saving casualty crashes, is illustrated in Figure 4. It can be seen that speeds below the 60 km/h limit are associated with a lower risk of a casualty crash, at the very least because they are associated with lower kinetic energy to produce injury in any crashes which occur.

Analysis of Melbourne individual speeds

The availability of the frequency of individual speeds in the 1% sample of covert mobile speed camera sessions in Melbourne 60 km/h zones [10] provided richer data for the analysis. In the following sections, the data was used to calculate the expected casualty crashes associated with each speed (and speed range), following Alavi et al's [10] method, and also the attributable fraction of crashes due to each speed range. These comparisons were made for each relative risk function and, in some cases, for different caps on the relative risk.

Relative risk related to difference from mean speed

Alavi et al's [10] analysis of individual speeds, weighting each by the relative risk equation (2) to provide an estimate [proportional to] casualty crashes, has been described above. However, their results provided only the expected casualty crashes and their distribution across the illegal speed ranges (Table 2), in particular the percentage associated with low-level speeding (up to 10 km/h above the limit). Here, Alavi et al's [10] analysis was extended to cover speeds between the mean speed and the limit, and below the mean speed (Table 4).

Table 4: Distribution of expected casualty crashes associated with each speed range, and attributable fraction of crashes due to speed above mean speed, Melbourne 2013. Relative risk as function of speed difference from mean speed, capped at risk for 74 km/h (21 km/h above mean)

Speed range (km/h)	Expected casualty crashes (sum of individual speeds by relative risk)	Percent of casualty crashes associated with speed range (%)	Attributable fraction (%)	Lower attributable fraction (%)	Upper attributable fraction (%)
Below mean	31,611.8	18.0%	-9.6%	-14.9%	-6.5%
Mean to limit	73,785.3	42.1%	15.5%	10.2%	25.4%
61-65	32,534.3	18.6%	14.0%	9.1%	24.7%
66-70	18,889.2	10.8%	9.7%	4.4%	22.7%
71-75	11,698.7	6.7%	6.4%	1.8%	21.5%
76-80	4,033.0	2.3%	2.2%	0.5%	8.3%
81+	2,627.0	1.5%	1.5%	0.3%	5.4%

Table 4 also shows the attributable fraction of casualty crashes due to each speed range, based on the relative risk equation (2) and its confidence limits. These limits were estimated from those tabled in Kloeden et al [2], Table 2.3, after taking natural logarithms as shown in Figure 5.

The function and limits were capped at the relative risks corresponding to 21 km/h above the speed limit, as done by Alavi et al [10], to maintain comparability of the results from the two analysis methods.

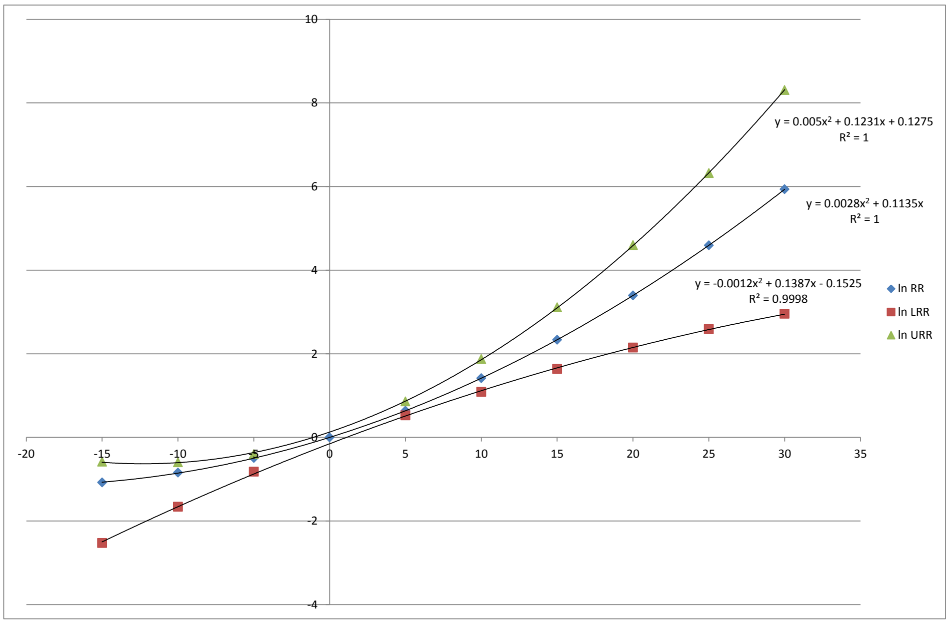


Figure 5: Natural logarithms of Kloeden et al's [2] relative risks (RR) and upper (URR) and lower (LRR) confidence limits versus speed difference from mean travel speed in 60 km/h limit zones

As implied by the points to the right in Figure 5, Kloeden et al [2] had provided confidence limits for their risk function (equation 2) at 25 and 30 km/h above the mean speed. Alavi et al [10] had capped the relative risk function at that for 21 km/h above the limit for their analysis. This had the effect of under-estimating the contribution of speeds above 74 km/h to the estimated expected crashes, and also to under-estimating the attributable fractions of crashes due to speeds in the 76-80 km/h and above 80 km/h ranges. The effect of this relatively low cap on relative risk can be seen in Table 5 where the cap has been reset at 83 km/h. This corresponds to a speed 30 km/h above the mean speed, which was the highest speed difference in 60 km/h limit zones that Kloeden et al [2] provided an estimated relative risk and confidence limits.

Table 5: Distribution of expected casualty crashes associated with each speed range, and attributable fraction of crashes due to speed above mean speed, Melbourne 2013. Relative risk as function of speed difference from mean speed (52.7 km/h), capped at risk for 83 km/h (30 km/h above mean)

Speed range (km/h)	Expected casualty crashes (sum of individual speeds by relative risk)	Percent of casualty crashes associated with speed range (%)	Attribut-able fraction (%)	Lower attribut-able fraction (%)	Upper attribut-able fraction (%)
Below mean	31,611.8	15.3%	-8.2%	-12.6%	-5.5%
Mean to limit	73,785.3	35.8%	13.1%	8.7%	21.6%
61-65	32,534.3	15.8%	11.9%	7.7%	21.0%
66-70	18,889.2	9.2%	8.3%	3.7%	19.3%
71-75	12,534.4	6.1%	5.9%	1.5%	20.6%
76-80	11,117.3	5.4%	5.3%	0.6%	32.5%
81+	25,615.2	12.4%	12.4%	0.6%	100.0%

It can be seen that the attributable fractions of crashes due to the higher speed ranges, when estimated using the higher cap on relative risk (that at 83 km/h compared with 74 km/h), are higher than those estimated using the lower cap. However these attributable fractions have wider limits, due to the greater uncertainty in the relative risk equation (2) at the higher speeds. Nevertheless, the estimates in Tables 4 and 5 are within each other's limits.

Tables 4 and 5 each provide estimates of the fraction of casualty crashes attributable to speeds above the mean speed, not just those attributable to speeding. Equation (2) applied to the distribution of individual speeds in 60 km/h limit zones suggests that relative risk is already 2.658 at the speed limit compared with the risk at the mean speed. Thus the attributable risk associated with each speeding range in Tables 4 and 5 starts from that base. In the following sections, the effect of using an estimate of risk relative to that at the speed limit (i.e., relative risks associated with speeding and not speeding) is examined.

Mean-centred risk referenced to risk at speed limit (60 km/h)

Equation (2) was rescaled by dividing it by the relative risk at the speed limit (i.e., $RR_2(60) = 2.658$). The rescaled relative risk function is:

$$RR_3(v) = RR_2(v) / RR_2(60) = \exp(-0.1133374*D + 0.0028171*D^2) / 2.658 \quad (3)$$

where D = (v – m). It then represents the risk of a casualty crash at each speed above and below the limit, relative to that at 60 km/h rather than relative to the mean speed. The effect of the rescaling on equation (2), the difference [from mean] risk, is shown in Figure 6. The rescaled function (solid line) has a relative risk of 1 at 60 km/h, but otherwise is proportional in shape to equation (2). Also shown in Figure 6 is equation (1), the relative risk associated with absolute speed in 60 km/h limit zones, relative to the risk at 60 km/h (small dashed line). It can be seen that the rescaled equation (3) is close to equation (1), but is higher at speeds above the speed limit.

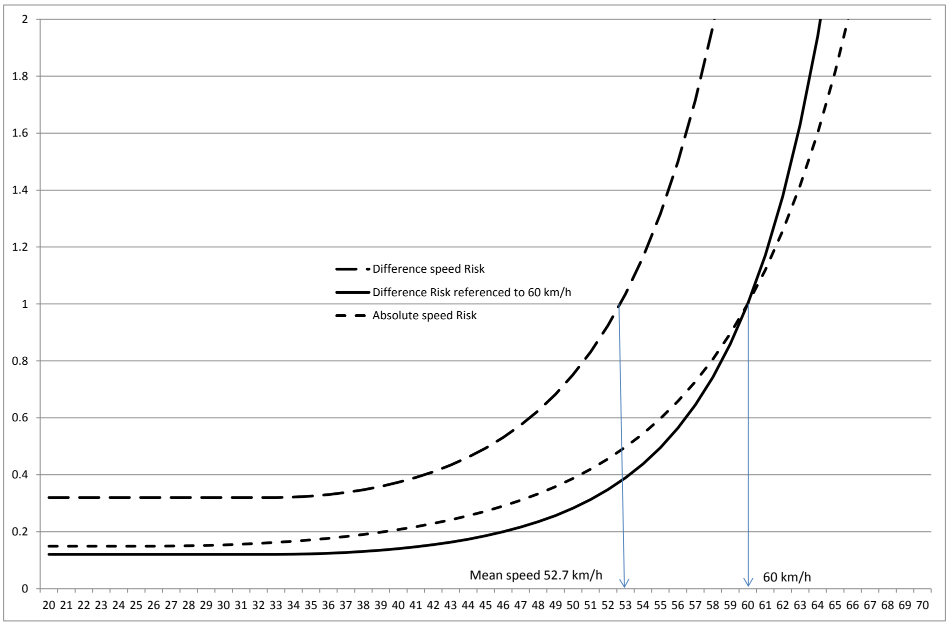


Figure 6: Relative risk functions in 60 km/h limit zones

The rescaled equation (3) was then applied to the individual speeds in the 1% sample of covert mobile speed camera sessions in Melbourne 60 km/h zones in the same way as the analysis reported in Table 5. The confidence limits on the relative risk function (2) were rescaled in the same way, i.e. dividing by 2.658. The results are shown in Table 6.

It can be seen that the distribution of expected casualty crashes over each speed range is the same as in Table 5. This is to be expected because the relative risk function has been divided by a constant and is otherwise unchanged, resulting in relativities being preserved.

However, Table 6 provides more appropriate estimates of the fractions of casualty crashes attributable to each level of speeding, in particular the estimates of the fractions attributable to low-level speeding. The estimated fractions attributable to the higher levels of speeding in Table 6 are almost identical to those estimated in Table 5. This is because the relative risks estimated at the higher speeds, no matter whether estimated by the raw or rescaled equation (2), both suggest very high attributable risks of similar magnitude. However, it should be noted that the attributable fractions due to higher level speeding ranges in both Tables 5 and 6 have high levels of uncertainty, as implied by the wide ranges of their limits.

Relative risk related to absolute speed in 60 km/h speed zones

A second method of examining the effect of using an estimate of risk relative to that at the speed limit, instead of risk relative to the mean speed, was to use equation (1). This function of relative risk related to the absolute speed in 60 km/h limit zones is shown in Figure 6. For consistency with previous analysis (Tables 5 and 6), the relative risk and its limits were capped at the highest speed (90 km/h) for which estimates were provided by Kloeden et al [2], Table 2.2. The results from using equation (1) are shown in Table 7.

It can be seen that the second method provides lower estimates of the attributable fraction of crashes due to speeds in each speeding range, compared with Table 6. The attributable fractions due to the higher speed ranges appear to be more reliable, based on the relative widths of their limits given in Table 7 compared with Table 6. The second method also provides estimates compatible with those in Table 3 based on aggregated speed ranges rather than individual speeds. However, this is to be expected given that the same relative risk function had been used in conjunction with the same raw speed data.

Table 6: Distribution of expected casualty crashes associated with each speed range, and attributable fraction of crashes due to speed above mean speed, Melbourne 2013. Relative risk as function of speed difference from mean speed, capped at risk for 83 km/h (30 km/h above mean), and rescaled by the risk at the speed limit (60 km/h), i.e. relative risk = 1 at 60 km/h

Speed range (km/h)	**Expected casualty crashes** (sum of individual speeds by relative risk)	**Percent of casualty crashes associated with speed range (%)**	**Attributable fraction (%)**	**Lower attributable fraction (%)**	**Upper attributable fraction (%)**
Below mean	11,894.1	15.3%	-47.1%	-51.6%	-44.5%
Mean to limit	27,762.1	35.8%	-24.4%	-28.9%	-16.0%
61-65	12,241.2	15.8%	5.5%	1.3%	14.6%
66-70	7,107.2	9.2%	6.8%	2.3%	17.8%
71-75	4,716.1	6.1%	5.5%	1.2%	20.2%
76-80	4,183.0	5.4%	5.3%	0.5%	32.4%
81+	9,637.8	12.4%	12.3%	0.6%	100.0%

Table 7: Distribution of expected casualty crashes associated with each speed range, and attributable fraction of crashes due to speed above mean speed, Melbourne 2013. Relative risk as function of absolute speed, capped at risk for 90 km/h (30 km/h above limit)

Speed range (km/h)	Expected casualty crashes (sum of individual speeds by relative risk)	Percent of casualty crashes associated with speed range (%)	Attribut-able fraction (%)	Lower attribut-able fraction (%)	Upper attribut-able fraction (%)
Below mean	16,460.8	23.2%	-45.1%	-54.0%	-31.2%
Mean to limit	31,617.8	44.6%	-21.3%	-28.4%	-15.3%
61-65	10,745.8	15.1%	3.9%	2.4%	6.0%
66-70	4,697.3	6.6%	4.0%	3.0%	6.1%
71-75	2,219.6	3.1%	2.5%	1.6%	4.7%
76-80	1,301.1	1.8%	1.7%	0.8%	4.5%
81+	3,905.2	5.5%	5.4%	1.3%	42.6%

Discussion

Capping the relative risk functions

In the analysis by Alavi et al [10] and this paper, the relative risk (RR) functions developed by Kloeden et al [2] have been capped at various levels, as follows:

- Mean-centred speed risk capped at 21 km/h above the mean speed of 52.7 km/h (RR = 37) (Alavi et al [10])
- Mean-centred speed risk capped at 83 km/h equal to 30 km/h above mean speed (RR = 411.7)
- Rescaled mean-centred speed risk capped at 83 km/h equal to 30 km/h above mean speed (RR = 154.9)
- Absolute speed risk capped at 90 km/h equal to 30 km/h above the 60 km/h speed limit (RR = 120.8)

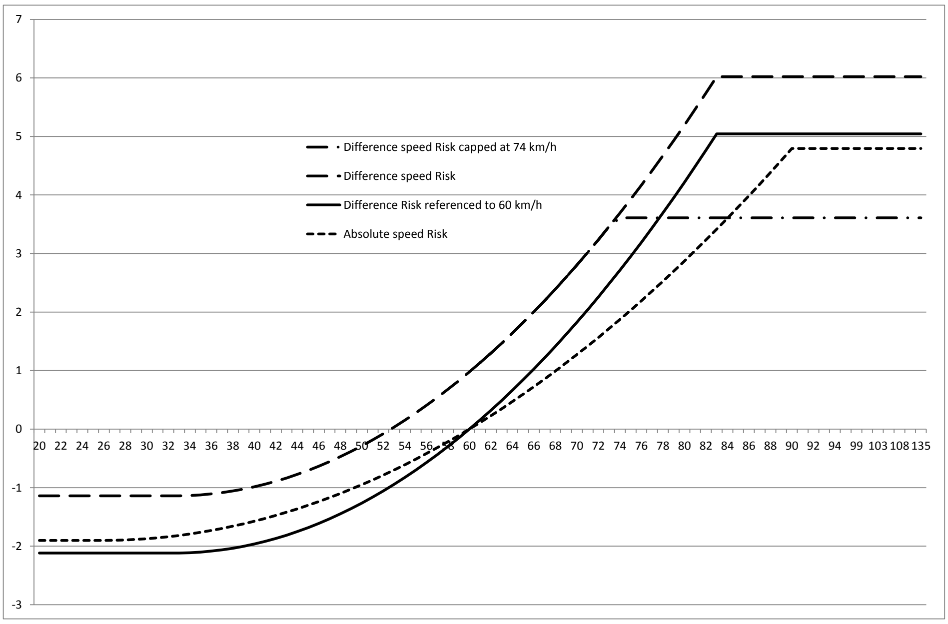


Figure 7: Natural logarithms of relative risk functions in 60 km/h limit zones

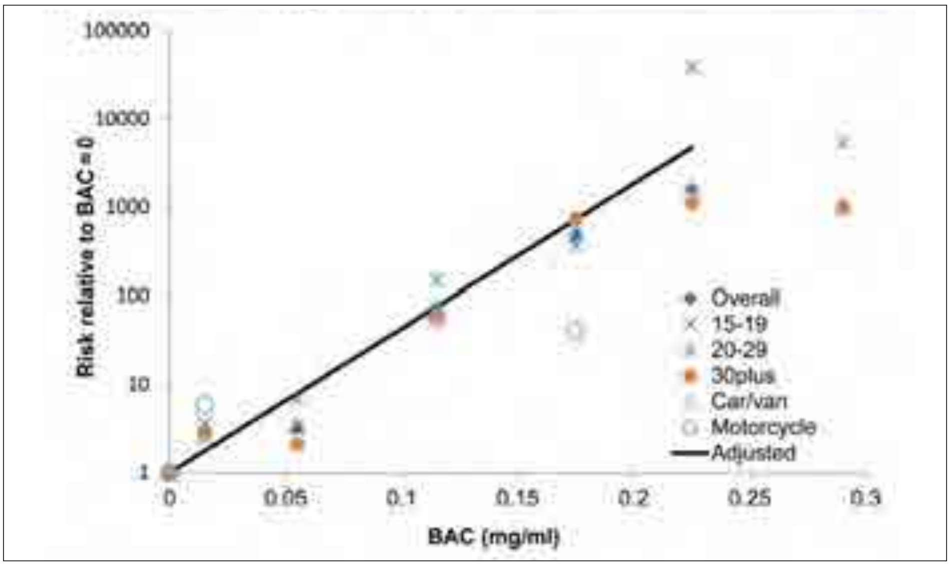


Figure 8: Logarithm of relative risk of driver/rider fatality versus BAC level for all drivers and specific driver age groups and vehicle types, estimated by Keall et al [12]

The last three caps were based on the highest speed (or speed difference) for which relative risk estimates and 95% confidence limits were provided by Kloeden et al [2], Tables 2.2 and 2.3. The influence of these caps is shown in Figure 7 based on the natural logarithm of each of the relative risk functions used in the analyses.

It could be expected that the true risk of a casualty crash in a 60 km/h limit zone would increase more than exponentially with speed, as implied by Kloeden et al's [10] functions, but eventually would asymptote to a level approaching certainty. It is unclear where this asymptotic level of risk lies in the case of speeding.

For drink-driving, the risk of a fatality appears to initially rise exponentially with blood alcohol concentration (BAC) and then asymptote at a risk about 1000 times that at zero BAC. Figure 8 shows the estimated risks provided by Keall et al [12].

On this basis, it would seem likely that the relative risk of a casualty crash associated with speeding could be up to 1000 times the risk at the mean speed or the speed limit in 60 km/h limit zones.

Thus, Alavi et al's [10] cap of the mean-centred risk function at a relative risk of 37 seems not to be supported by the possibility that the true risk is approaching an asymptote at 21 km/h above the mean speed. While the use of Kloden et al's [2] mean-centred risk function at higher speeds should be done with caution, the availability of confidence limits on the function allows the uncertainty in estimates from it to be provided (as done for the estimates of attributable risk fractions in Tables 3 to 7).

Risk related to mean-centred speed compared with absolute speed

Attributable risk fractions based on the mean-centred risk function, equation (2), are different from estimates of attributable fractions based on the absolute speed function, equation (1). The fractions of crashes estimated from equation (2) are those attributable to speeds in ranges above the mean speed, including some speeding ranges, but are not directly attributable to the speeding (range) *per se*. This is because the reference point for equation (2) is the mean speed, not the speed limit like equation (1).

However, the rescaled mean-centred speed risk function (3) is referenced to the 60 km/h limit. This was achieved by dividing the risk function (2) by the relative risk at 60 km/h, relative to the risk of 1 at the mean speed (which is the reference for the raw mean-centred risk function). If the true mean-centred speed risks were known absolutely, then exactly the same rescaled mean-centred relative risks would be obtained by dividing each absolute risk at a given speed by the absolute risk at 60 km/h.

Figures 6 and 7 show that the rescaled mean-centred risk function (3) and the absolute speed risk function (1) are not greatly different in shape and scale, and their caps are at similar levels. The limits on the attributable fraction estimates from the rescaled mean-centred risk function (Table 6) generally cover the limits from the absolute speed risk function (Table 7), although the magnitudes of some fraction estimates are different. In general, it appears that the two risk functions produce similar results when applied to speed data from 60 km/h limit zones, provided attention is given to the uncertainty in each function at the higher speeds.

Estimating attributable risk fractions in other speed limit zones

Kloeden et al's [2] relative risk functions were developed only for 60 km/h limit zones in an urban area. There is the question of whether they could be applied to estimate the relative risk of casualty crashes, and the attributable fractions due to each speed(ing) range, in other urban speed limit zones. It is not possible to address that question directly because Kloeden et al's [1] function related to absolute speed has not been calibrated for other than 60 km/h speed limit zones. However, the results of this paper provide some confidence that the mean-centred risk function, equation (2), based on each zone's mean speed and rescaled to the relative risk at the zone's speed limit, could be so applied.

Kloeden et al [13] provided a relative risk function of the difference between each specific speed and the mean speed in rural speed limit zones ranging from 80 to 110 km/h. Again, the results of this paper provide some confidence that their rural mean-centred risk function, based on the zone's mean speed and rescaled to the relative risk at the zone's speed limit, could be applied to estimate the attributable fractions due to rural speeding.

Comparison of Melbourne with Perth and urban Queensland

The most direct comparison was between attributable fractions associated with each speeding range shown in Tables 1 and 3, where the same analysis method was applied to speeds recorded in ranges generally 5 km/h wide. In Melbourne, about 7% of casualty crashes were attributable to high level speeding (more than 20 km/h above the 60 km/h limit), compared with 24% to 34% in Perth and urban Queensland. At the other extreme, about 9% of casualty crashes were attributable to low level speeding (up to 10 km/h above the limit) in Melbourne, compared with 12% to 16% in urban areas in the other two States.

The Melbourne results in Table 3 were generally confirmed by the analysis of individual speeds, when the relative risk function was not capped unduly and when the mean-centred function was rescaled (Tables 6 and 7). Analysis of individual speeds suggested that 5% to 12% of casualty crashes were attributable to high level speeding, and 8% to 12% were attributable to low level speeding. It should be noted that the attributable fractions associated with high level speeding have wide confidence limits, but the separate estimates are within each other's limits.

Thus it seems clear that the pattern of speeding and its contribution to casualty crashes in Melbourne 60 km/h limit zones was very different from that in Perth and urban Queensland. The magnitude of the difference appears greater than that which could be explained by the distribution of speeds recorded by covert mobile speed cameras not being representative of all speeds on Melbourne 60 km/h roads.

The full explanation for the difference in speeding patterns in Melbourne compared with Perth and urban Queensland is beyond the scope of this paper, but may lie with the influence of Victoria's different operation of mobile speed cameras (covert versus overt) and other speeding-related initiatives.

Conclusions

1. A low cap placed on Kloeden et al's [2] relative risk functions is not justified in analysis to estimate the association and attribution of observed speeds with casualty crashes.

2. Analysis using Kloeden et al's [2] relative risk functions with higher caps should make use of the 95% confidence limits provided by the original authors.

3. The rescaled mean-centred speed relative risk function, referenced to the risk at the speed limit, provides similar results to the relative risk function based on the absolute speed in 60 km/h limit zones.

4. Because of conclusion three, the mean-centred speed relative risk functions [2, 13] could be applied with some confidence to estimate the casualty crash risk, relative to that at the speed limit, at free speeds in other urban and rural speed limit zones apart from the 60 km/h zone.

5. The pattern of speeding and its contribution to casualty crashes in Melbourne 60 km/h limit zones during 2013 was very different from that in 60 km/h zones in Perth and urban Queensland during 2010.

References

1. Cameron, MH. Use of Kloeden et al's relative risk curves and confidence limits to estimate crashes attributable to low and high level speeding. Journal of the Australasian College of Road Safety; 24(3): 40-52, 2013.

2. Kloeden, CN, McLean, AJ, and Glonek, G. Re-analysis of travelling speed and the rate of crash involvement in Adelaide, South Australia. Report CR 207, Australian Transport Safety Bureau, Canberra, Australia, 2002.

3. D'Elia, A, Newstead, S, Cameron, M. Use and Validation of Risk-Weighted Speed Observation Data for Countermeasure Evaluation. Proceedings of the Australasian Road Safety Research, Policing and Education Conference, Adelaide, 2008.

4. Gavin, A, Walker, E, Murdock, C, Graham, A, Fernandes, R, Job, RFS. Is a focus on low level speeding justified? Objective determination of the relative contributions of low and high level speeding to the road toll. Proceedings of 2010 Australasian Road Safety Research, Policing and Education Conference, 2010.

5. Gavin A, Walker E, Fernandes R, Graham A, Job RFS, Sergeant J. Creation and validation of a tool to measure the real population risk of speeding. Proceedings of the Australasian Road Safety Research, Policing and Education Conference, 2011.

6. Doecke, SD, Kloeden, CN, McLean, AJ. Casualty crash reductions from reducing various levels of speeding. CASR076. Centre for Automotive Safety Research, Adelaide, 2011.

7. Holman, CDJ. Attributable fraction analysis of illegal speeding and road crashes. Report to Road Safety Council of Western Australia. School of Population Health, University of Western Australia, Perth, 2011.

8. Elvik, R. Dimensions of road safety problems and their measurement. Accident Analysis and Prevention; 40: 1200-1210, 2008.

9. Walter, SD. The estimation and interpretation of attributable risk in health research. Biometrics; 32: 829-49, 1976.

10. Alavi, H, Keleher, S, Nieuwesteeg, M. Quantifying the contribution of low-level speeding to road trauma in Victoria. Proceedings of 2014 Australasian Road Safety Research, Policing and Education Conference, 2014.

11. Nieuwesteeg, M, Alavi, H. The good news about speed compliance in Victoria. Proceedings of 2014 Australasian Road Safety Research, Policing and Education Conference, 2014.

12. Keall, M, Clarke, B, Rudin-Brown, C. A preliminary investigation of motorcyclist fatal injury risk by BAC level relative to car/van drivers. Traffic Injury Prevention; 14; 7-12, 2013.

13. Kloeden, CN, Ponte, G, and McLean, AJ. Travelling speed and the rate of crash involvement on rural roads. Report CR 204, Australian Transport Safety Bureau, Canberra, Australia, 2001.

speeding (up to 10 km/h above the limit) in Melbourne, compared with 12% to 16% in urban areas in the other two States.

The Melbourne results in Table 3 were generally confirmed by the analysis of individual speeds, when the relative risk function was not capped unduly and when the mean-centred function was rescaled (Tables 6 and 7). Analysis of individual speeds suggested that 5% to 12% of casualty crashes were attributable to high level speeding, and 8% to 12% were attributable to low level speeding. It should be noted that the attributable fractions associated with high level speeding have wide confidence limits, but the separate estimates are within each other's limits.

Thus it seems clear that the pattern of speeding and its contribution to casualty crashes in Melbourne 60 km/h limit zones was very different from that in Perth and urban Queensland. The magnitude of the difference appears greater than that which could be explained by the distribution of speeds recorded by covert mobile speed cameras not being representative of all speeds on Melbourne 60 km/h roads.

The full explanation for the difference in speeding patterns in Melbourne compared with Perth and urban Queensland is beyond the scope of this paper, but may lie with the influence of Victoria's different operation of mobile speed cameras (covert versus overt) and other speeding-related initiatives.

Conclusions

1. A low cap placed on Kloeden et al's [2] relative risk functions is not justified in analysis to estimate the association and attribution of observed speeds with casualty crashes.

2. Analysis using Kloeden et al's [2] relative risk functions with higher caps should make use of the 95% confidence limits provided by the original authors.

3. The rescaled mean-centred speed relative risk function, referenced to the risk at the speed limit, provides similar results to the relative risk function based on the absolute speed in 60 km/h limit zones.

4. Because of conclusion three, the mean-centred speed relative risk functions [2, 13] could be applied with some confidence to estimate the casualty crash risk, relative to that at the speed limit, at free speeds in other urban and rural speed limit zones apart from the 60 km/h zone.

5. The pattern of speeding and its contribution to casualty crashes in Melbourne 60 km/h limit zones during 2013 was very different from that in 60 km/h zones in Perth and urban Queensland during 2010.

References

Cameron, MH. Use of Kloeden et al's relative risk curves and confidence limits to estimate crashes attributable to low and high level speeding. Journal of the Australasian College of Road Safety; 24(3): 40-52, 2013.

Kloeden, CN, McLean, AJ, and Glonek, G. Re-analysis of travelling speed and the rate of crash involvement in Adelaide, South Australia. Report CR 207, Australian Transport Safety Bureau, Canberra, Australia, 2002.

D'Elia, A, Newstead, S, Cameron, M. Use and Validation of Risk-Weighted Speed Observation Data for Countermeasure Evaluation. Proceedings of the Australasian Road Safety Research, Policing and Education Conference, Adelaide, 2008.

Gavin, A, Walker, E, Murdock, C, Graham, A, Fernandes, R, Job, RFS. Is a focus on low level speeding justified? Objective determination of the relative contributions of low and high level speeding to the road toll. Proceedings of 2010 Australasian Road Safety Research, Policing and Education Conference, 2010.

Gavin A, Walker E, Fernandes R, Graham A, Job RFS, Sergeant J. Creation and validation of a tool to measure the real population risk of speeding. Proceedings of the Australasian Road Safety Research, Policing and Education Conference, 2011.

Doecke, SD, Kloeden, CN, McLean, AJ. Casualty crash reductions from reducing various levels of speeding. CASR076. Centre for Automotive Safety Research, Adelaide, 2011.

Holman, CDJ. Attributable fraction analysis of illegal speeding and road crashes. Report to Road Safety Council of Western Australia. School of Population Health, University of Western Australia, Perth, 2011.

Elvik, R. Dimensions of road safety problems and their measurement. Accident Analysis and Prevention; 40: 1200-1210, 2008.

Walter, SD. The estimation and interpretation of attributable risk in health research. Biometrics; 32: 829-49, 1976.

Alavi, H, Keleher, S, Nieuwesteeg, M. Quantifying the contribution of low-level speeding to road trauma in Victoria. Proceedings of 2014 Australasian Road Safety Research, Policing and Education Conference, 2014.

Nieuwesteeg, M, Alavi, H. The good news about speed compliance in Victoria. Proceedings of 2014 Australasian Road Safety Research, Policing and Education Conference, 2014.

Keall, M, Clarke, B, Rudin-Brown, C. A preliminary investigation of motorcyclist fatal injury risk by BAC level relative to car/van drivers. Traffic Injury Prevention; 14; 7-12, 2013.

Kloeden, CN, Ponte, G, and McLean, AJ. Travelling speed and the rate of crash involvement on rural roads. Report CR 204, Australian Transport Safety Bureau, Canberra, Australia, 2001.

Transport-related fatalities and injuries leading to hospitalisation in pre-school children

by Victor Siskind

Centre for Accident Research and Road Safety – Queensland (CARRS-Q), Queensland University of Technology, K Block, 130 Victoria Park Road, Kelvin Grove, Queensland, v.siskind@qut.edu.au

Abstract

Pre-school children grow and develop rapidly with age and their changing capabilities are reflected in the ways in which they are injured. Using coded and textual descriptions of transport-related injuries in children under five years of age from the Queensland Injury Surveillance Unit (QISU) this paper profiles the modes of such injuries by single year of age. The QISU collects information on all injury presentations to emergency department in hospitals throughout Queensland using both coded information and textual description. Almost all transport-related injuries in children under one year are due to motor vehicle crashes but these become proportionately less common thereafter, while injuries while cycling become proportionately more common with age. Slow-speed vehicle runovers peak at age one year but occur at all ages in the range. Bicycle-related fatalities are rare in this age group. If bicycle-related injuries are excluded, the profiles of fatal and non-fatal injuries are broadly similar. Comparison with a Queensland hospital series suggests that these results are broadly representative.

Keywords

Injuries, Hospitalisation, Pre-school children, Transport-related injuries

Introduction

The first few years of a child's life are marked by rapid growth and developmental changes. This fact is reflected in the changing patterns of injury suffered by children under five years of age [1, 2], both across and within broad categories of injury, which is as true for transport-related injuries as for any other injury mode. Few if any studies of transport-related injuries or fatalities in young children report the mechanisms of such injuries by sufficiently narrow age bands. The usual age breakdown reported is by five-year bands - with some studies separating out infants under one year - obscuring the substantial age-related alterations in modes of injury in children under five years in particular [3, 4, 5]. Moreover, most of the studies of transport-related injuries in young children focus on fatalities; while always tragic, such fatalities are relatively rare, at least in developed countries such as Australia, and may not be representative of the much larger number of non-fatal injuries. Without a more detailed understanding of how injury patterns change by age, preventive interventions for this age group are likely to be less efficiently targeted than they could be.

From analysis of a file supplied by the Queensland Hospital Admitted Patient Data Collection, 1237 children under the age of five years were admitted to Queensland hospitals for a transport-related injury over the period, July 2002 to June 2007, a rate of 96.0 per 100,000. From January 2004 to June 2013, a total of 92 children aged 0 to 4 years were killed in transport-related incidents, a rate of 3.4 per 100,000, as reported by the now superseded Commission for Children and Young People, Queensland. While such injuries form a fairly small proportion of hospitalised injuries from external causes, as reported below, transport-related fatalities formed almost 30% of the deaths in children under five years of age in the reports of the Commission for Children and Young People, Queensland.

Recent road safety strategies for Queensland make no specific mention of children, although the Queensland Department of Transport and Main Roads issued a motorcyclist riding guide which makes brief mention of children's safety without specifying to which ages it applied [6].

This study aims to detail the ways in which children under five years of age admitted to hospital are injured in transport-related incidents by single year of age, using data generated in Queensland. Wherever possible it makes comparisons with the types of transport-related incidents in which children in this age group and jurisdiction are fatally injured.

As noted above, most if not all studies of transport-related injuries in children under five years of age treat this age group as a whole or in some instances with children under one year of age as a separate category. The latter age categorisation is the one in use in the reports of the Commission for Children and Young People, Queensland. In Australia one report describes the "place of occurrence and road user group of children aged under five years seriously injured in a land transport accident" in the financial year 2006-07 year [3], finding 6% to have been injured in the driveway of the home, and 37% in the street or highway, but with 38% in an unspecified location. A second Australian paper gives the distribution of modes of transport-related injuries in children under five years of age as "Car 23%, Pedestrian 25% and Pedal cycle 32%" [4]. A report from the USA on deaths and non-fatal injury indicated that transport-related injuries were the second leading cause of unintentional injury death in children under one year of age at 3.7 per 100,000, and the leading cause in children in the age range one to four years at 4.2 per 100,000. Among non-fatal injuries, transport-related injuries comprised 4% and 5% of hospital admissions for unintentional injury in children aged under one year and one to four years, respectively, with a rates of 237 and 697 per 100,000 respectively [5].

Slow-speed vehicle run-overs (SSVROs) have been studied for many years in a variety of jurisdictions. In Queensland the most thorough analysis was recently published using data from a number of complementary local sources [7]. The authors provide a substantial list of references on the topic. Apart from incidence, children under one year of age are not considered separately from children age one to four years.

Methods

The data on non-fatal injuries were supplied by the Queensland Injury Surveillance Unit (QISU) for the years 2002 to 2012 and contain both descriptive text and coded variables. A detailed description of the structure and methods of the QISU can be found in [2]. The QISU data include all ED injury presentations including those patients who may present for treatment of a suspected injury, where no anatomical injury is found, or where the injury is minor enough for the patient to be treated and then released home from the ED. For these analyses only those patients under five years of age who had an injury deemed sufficiently severe to warrant admission to hospital for further treatment were included. The sample thus represents the more serious end of the severity spectrum.

Coded variables identify transport-related injuries and provide some information on mode of injury, whereas the textual descriptions often give a more detailed picture of how the injury occurred. The combination of these variables make it possible in the majority of cases to assign the injury cause accurately to the following categories: motor vehicle crash (as passenger); struck by motor vehicle, in particular, slow-speed vehicle run-over; struck by pedal cycle; bicycle crash; motor-cycle associated; quad bike associated; and other and unknown. For motor vehicle crashes, in many instances a comment was made in the text indicating whether or not the child had been restrained, and this has been noted, although it was not always possible to establish how appropriate for the child's age and size the restraint had been.

Modes of fatal injury are described in the annual reports of the Queensland Commission for Children and Young People (2004/5 to 2012/13) accessible via the National Library of Australia [8]. In these reports the age breakdown among children under five years of age is less than a year and 1 - 4 years. For the purposes of this study, incidents involving stationary motor vehicles and atypical transport modes, such as ride-on mowers and farm machinery, which together comprise about 5% of incidents, are excluded. Incidents involving watercraft are also not considered.

A further comparison is made with injuries to children under five years of age admitted to Queensland hospitals over the period mid-2002 to mid-2007. No finer age breakdown was provided. In this instance categorisation of modes of injury is by means of the ICD10-AM codes.

Transport-related injuries were those so classified by QISU or the Commission for Children and Young People, Queensland, or in the hospital file, ICD10-AM codes with alphabetic code V, except that falls from clearly stationary vehicles other than bicycles, atypical transport modes, burns from hot vehicle parts and water transport injuries were excluded.

Since all data files contain non-identifiable records, the study was deemed to be exempt from formal approval by the relevant institutional Research Ethics Committee. In this descriptive study formal statistical analysis was not considered appropriate for this study.

Results

There were in the QISU file 542 hospitalised children under five years of age with transport-related injuries, representing 4.4% of all admissions in this age group. The breakdown by age (in single years) and injury mechanism is given in Table 1. Almost all injuries to infants under one year of age are due to being a passenger in a motor vehicle crash. In older children the proportion due to motor vehicle crashes fluctuates around 30 – 40%. Restraint use is on the whole poorly documented, especially in children over a year old, nor is it always clear whether the restraint reported is age-appropriate. In children aged under one year baby capsules are mentioned in a quarter of instances.

Table 1.Transport-related injuries in children < 5 years old, 2002 – 2012

Age of patient (yrs)	< 1		1		2		3		4	
Type of incident	N	%	N	%	N	%	N	%	N	%
MVC	48	94.1	29	28.7	44	44.0	49	36.6	51	32.7
Struck by vehicle	3	5.9	48	47.5	27	27.0	33	24.6	27	17.3
SSVRO	*1*	*2.0*	*37*	*36.6*	*16*	*16.0*	*7*	*5.2*	*9*	*5.8*
Bicycle	0	0.0	15	14.9	20	20.0	31	23.1	67	42.9
Motorcycle	0	0.0	2	2.0	1	1.0	5	3.7	8	5.1
Quad bike	0	0.0	4	4.0	3	3.0	9	6.7	2	1.3
Other/unknown	0	0.0	4	4.0	5	5.0	7	5.2	1	0.6
Total	51	100	101	100	100	100	134	100	156	100
% of all admissions	*2.3*		2.8		3.3		5.6		*7.6*	

MVC: Motor vehicle crash. Source: Queensland Injury Surveillance Unit

Being struck by a motor vehicle, and being run over at slow speed in particular, peaks as a proportion of incidents in children aged one year, occurring in more than a third of one-year-old children, 16% of two-year-olds and five to six percent in children aged three or four years. In about a third of slow-speed runovers the vehicle was reversing at the time of the incident. In a few instances, a child was struck by a motor vehicle while riding a bicycle or tricycle and in 10 instances at ages one to three years the child was struck and injured by a pedal cycle. Bicycle-related injuries without involvement of a motor vehicle become increasingly common from one year of age onward, comprising close to half of all injuries by age four years. Injuries associated with motor-cycles and all-terrain vehicles ("quad bikes") are less common, but occur at all ages except the youngest. They together account for 8% of injuries at ages one and two, 12% at age three and 2% at age four. It seems from the textual descriptions that in some instances the child himself or herself was in at least partial control of the vehicle. As a proportion of all admissions transport-related injuries increase steadily with age from 2.3% in children under one year of age to 7.6% in four-year-olds. This increase is partially due to the increase in bicycle-related injuries.

From 2004 to 2013 there were a total of 92 transport-related deaths of children under five years of age, 13 under one year (Table 2). Six children have been excluded from the analysis, three having been killed by machinery, two in boating incidents and one in a fall from a stationary vehicle. In children under one year of age, almost all deaths were due to motor vehicle crashes, as in the case of non-fatal injuries. In older children motor vehicle crashes accounted for about two-fifths of fatalities, while almost one half were as pedestrians. As in the case of non-fatal injuries, deaths associated by motor-cycles and quad bikes comprise a small proportion (5.4%) of all fatalities. No fatalities associated with bicycles were recorded during this period.

Table 2. Transport-related deaths in Queensland children under 5 years of age, January 2004 - June 2013

Age	**< 1 year**		**1 – 4 years**	
Mode of death	N	%	N	%
Passenger in motor vehicle	11	84.6	30	41.1
Pedestrian	1	14.6	36	49.3
Slow-speed vehicle run-over	*1*	*14.6*	*20*	*27.4*
Quad bike	0	0.0	2	2.7
Motor cycle	0	0.0	2	2.7
Other/unknown	1	14.6	3	4.3
Total	13	100.0	73	10.00

Source: Queensland Commission for Children and Young People

A comparison between the modes of fatal and non-fatal injuries is given in Table 3.Children injured in bicycle-associated incidents have been excluded to facilitate the comparison. In both children under one and children age one to four years the distributions of modes of injury are broadly similar, the main difference being an excess of pedestrians among the fatally injured and a corresponding increase of non-fatal injuries due to motor vehicle crashes.

Table 3. Comparison of fatal and non-fatal injury patterns, excluding bicycle use

Age group	< 1 year		1 – 4 years	
Mode of death/injury	Deaths	Injury	Deaths	Injury
Passenger in motor vehicle	84.6	94.1	41.1	47.0
Pedestrian	7.7	5.9	49.3	39.4
Slow-speed vehicle run-over	*7.7*	*2.0*	*27.4*	*18.8*
Quad bike/Motor-cycle	0.0	0.0	5.5	9.2
Other/Unknown	7.7	0.0	4.1	4.3
Total	100	100.0	100.0	100.0

As a rough guide to the representative of the QISU sample, a comparison is made in Table 4 between the distribution of modes of injury obtained from all hospitalisations in Queensland from 2002/3 to 2006/7 and that from the QISU, for all children under five years of age. The categorisations are admittedly not precisely the same, but are close enough for a valid comparison.

The major differences between the two series is the greater proportion of other and unspecified modes and the over-representation of injuries classified as motorcycle-related versus injuries classified as quad-bike-related in the Queensland hospital data. Thus it is reasonable to claim that the QISU sample is broadly reflective of the pattern of transport-related injuries in Queensland preschoolers.

Table 4. Patients under 5 years of age admitted to Queensland Hospitals 2002/3-2006/7 compared to admitted patients under 5 years of age in the QISU sample

Patient classification	N[1]	% (QH)	% (QISU)
Person injured in a motor vehicle crash	436	**35.7**	**40.0**
Pedestrian	255	**20.9**	**26.8**
struck by motor vehicle	*247*	*20.2*	*25.0*
struck by bicycle	*8*	*0.7*	*1.8*
Cyclist	348	**28.5**	**24.1**
struck by vehicle	*17*	*1.4*	
non-collision	206	16.9	
unspecified	125	10.2	
Motor-cyclist/pillion passenger	62	**5.1**	**2.9**
Occupant of quad bike	22	**1.8**	**3.3**
Other and unspecified	97	**8.0**	**2.9**
Total	1220	**100.0**	**100.0**

Source: Queensland Hospital Admitted Patient Data Collection July 2002-June 2007

Discussion

As anticipated, modes of injury in children under five years of age vary substantially with the age of the child, reflecting the greater mobility and enhanced general capabilities of developing children. Almost all transport-related injuries to infants under a year occur in motor vehicle crashes, whereas by age four this mode represents about a third of such injuries. Restraint use in motor vehicle crashes tends to be poorly documented, but there are indications that a proportion of pre-school children of all ages are improperly restrained.

Slow-speed runovers occur at all ages but are a particular problem at ages one, in particular, and two years of age, as noted in the case of fatalities by Griffin and colleagues [9]. Children older than two years are presumably more mobile and alert to their surroundings, and hence better able to avoid slowly moving vehicles.

Bicycle-related injuries are uncommon in children aged one or two years, but by age four comprise the largest proportion of transport related injuries at over 40%. They are apparently rare among fatalities, which is consistent with the low rate of cycle-related deaths in a report from the USA [5]. It may be that children killed by a motor vehicle while riding a bicycle are not always distinguished in published tables from children killed as pedestrians. As far as can be inferred from length of hospital stay, bicycle-related injuries in children under five years of age tend to be on average less severe (mean length of hospital stay = 1.5 days) than those associated with other modes of injury (mean length of hospital stay = 3.8 days) . Nonetheless closer supervision of cycling in preschool children should perhaps be encouraged. Further research on this topic is warranted.

On the other hand it is arguable that riding on motorcycles or quad bikes by such young children, whether as passengers or controllers, entirely or partially, is not to be encouraged. There is evidence of an increase over time in injuries related to these vehicles from both Victoria [10] and in the current data. The American Academy of Pediatrics in 2000 recommended that children and adolescents under the age of 16 should not be permitted to be in control of a motorcycle or all-terrain vehicle and that riding pillion on these vehicles should be discouraged in younger children [11]. While there is merit in such a stringent approach, it is unlikely to be favourably received in either the USA or Australia, and efforts should rather be directed to harm minimisation.

Wider understanding of the patterns of transport-related injury would better inform heath service providers dealing with small children, such as health nurses and paediatricians, as to the advice they should give to parents of children under five years of age. Much of this advice, with a lower level of age specificity, can be found in the fact sheets to be found on the website of Kidsafe Queensland [12].

One limitation of this study is the variable quality of the textual descriptions available, due in large part to the busy nature of the emergency departments in which the information is collected and also to the number of transfers from the first point of contact of the injured child with health services. In particular there is not enough information on the adequacy of child restraints in motor vehicle crashes. A special investigation may be needed to gain better information in this.

Another limitation is the partial nature of the QISU's coverage of Queensland hospitals. However over 86% of children under five years of age were admitted to one or other of the two major children's hospitals in Brisbane, frequently after transfer from another facility, so that coverage is less of a problem than in older persons. The hospital admitted patient data are however comprehensive.

References

1. Schmertmann M, Williamson A, Black D. Leading causes of injury hospitalisation in children aged 0–4 years in New South Wales by injury submechanism: A brief profile by age and sex. Journal of Paediatrics and Child Health, 2012, 48:978-984
2. Siskind, V, Scott, D. Injuries leading to hospitalisation in the first year of life: analysis by trimester of age using coded data and textual description. Australian and New Zealand Journal of Public Health, 2013, *37*:168-172.
3. Henley G, Harrison JE. Serious injury due to land transport accidents, Australia 2006–07. Injury Research and Statistics series no. 53. Cat. no. INJCAT 129. 2009,Canberra: AIHW.
4. Ivers R. Paediatric injuries: burden, risk factors and effective interventions. The George Institute, 2014. www.kidsfamilies.health.nsw.gov.au/publications/paediatric-injury-prevention-management-research.
5. Borse NN, Gilchrist J, Dellinger AM, Rudd RA, Ballesteros MF, Sleet DA. CDC Childhood Injury Report: Patterns of Unintentional Injuries among 0 -19 Year Olds in the United States, 2000-2006. Atlanta (GA): Centers for Disease Control and Prevention, National Center for Injury Prevention and Control; 2008
6. Department of Transport and Main Roads, Queensland Motorcycle Riders' Guide, 2012.
7. Griffin B, Watt K, Wallis B, Shields L, Kimble R. Incidence of paediatric low speed vehicle run-over events in Queensland, Australia: eleven year analysis. BMC public Health, 2014, 14:245-252.
8. National Library of Australia publications. http://pandora.nla.gov.au/pan/14014/20130121-0000/www.ccypcg.qld.gov.au/resources/publications/reports.html
9. Griffin B, Watt K, Wallis B, Shields L, Kimble R. Paediatric low speed run-over fatalities in Queensland. Inj Prev 2011; 17:i10-13.
10. Bevan CA, Babl FE, Bolt P, Sharwood LN. The increasing problem of motorcycle injuries in children and adolescents. Med J Aust 2008; 189:17-20.
11. American Academy of Pediatrics, Committee on Injury and Poison Prevention. All-Terrain Vehicle Injury Prevention: Two-, Three-, and Four-Wheeled Unlicensed Motor Vehicles. Pediatrics, 2000, 105: 1352-54.
12. Kidsafe Queensland. http://www.kidsafeqld.com.au/publications/fact-sheets.

Contributed articles

Recent research on safe roads and infrastructure

by Blair M Turner
ARRB Group Ltd
blair.turner@arrb.com.au

Introduction

Safe roads and infrastructure are key factors in the likelihood and severity outcome of road crashes. Although the vast majority of crashes are as a result of some form of human error, or of human error in combination with the road and/or the vehicle, we also know that the greatest determinant of crash severity will be the infrastructure that is provided. As an example, Stigson et al. [1] reviewed fatal crashes based on in-depth crash investigation, with crashes categorised based on factors that contributed to the crash outcome (as opposed to crash causation). Their study found that there were strong interactions between the different pillars of the 'system' (road user, road and vehicle), but also that the road and roadside were the most strongly linked to fatal crash outcomes. Further evidence for the importance of infrastructure comes from evaluations of safety treatment effectiveness. Individual infrastructure treatments, or treatments used in combination can significantly reduce death and serious injury. The most recent BITRE evaluation of the federal blackspot funding program showed that benefits from targeted infrastructure treatments outweighed the costs by a factor of 8 to 1 [2]. As an example, well-designed roundabouts are able to virtually eliminate deaths at intersections (by up to 80% [2]). When joined with benefits from other Safe System pillars (including vehicle improvements, speed management and improvement in road user behaviour) the combined benefits will be greatest.

Based on Austroads figures [3], roads are the largest asset owned by the community in Australia and New Zealand. They suggest the value of the road asset is around $200 billion, and that every year, $18 billion is spent on maintenance and construction. Some of this investment will have direct safety benefits. There are also significant investments made in infrastructure safety programs, including the federally-funded blackspot program. It is important to fine-tune this investment to ensure that societal benefits from infrastructure improvements are maximised.

Despite the annual investment in infrastructure, and the potential for safety improvements through this mechanism, the level of research conducted on this issue is extremely limited. ARRB Group (ARRB; formerly the Australian Road Research Board) has been working on the topic of safe roads and infrastructure for a number of decades. The issue is of high interest to ARRB's members who include Australian and New Zealand federal, state and local government bodies responsible for managing the nation's road networks. This paper outlines recent research relating to safe roads and infrastructure; particularly work undertaken at the national level for Austroads, or for individual state road agencies. Much of this work is 'applied' in nature, aimed at providing direct guidance and tools to assist road agencies and practitioners in implementing findings to help improve the management of road infrastructure.

Themes for research

ARRB research on road infrastructure has been varied, extending beyond safety. Core areas of research include issues relating to the design, construction, management, maintenance, operation and use of the road network. The following sections concentrate on research relating to safe roads and infrastructure. Research on this topic generally falls into a number of themes, or research programs. Several of these are described below, including those that relate to:

- Safe System infrastructure
- Crash risk assessment
- Effectiveness of road safety treatments (Crash Modification Factors)
- Speed research, and the speed/infrastructure relationship
- Addressing key crash types and user groups by improving infrastructure
- Data and benchmarking
- Development of road safety tools and dissemination.

Safe System infrastructure

The Safe System approach was adopted a number of years ago in Australia. Although the concepts are now wellunderstood, the direct actions required by road agencies to implement improvements to infrastructure are less well developed. Intensive research on the implementation of Safe System infrastructure commenced in 2009, with a workshop involving key road agency stakeholders [4]. This event was an important forum for discussing the approaches being taken by road agencies, and emerging gaps in knowledge. One of the key outcomes from this event was that a distinction was drawn between different types of road infrastructure treatments. Some treatments provide substantial safety improvements, moving us close to the Safe System objective of eliminating death and serious injury. These were termed 'primary' treatments and include treatments such as grade separation, roundabouts, and raised platforms at intersections; roadside protection through the use of wire rope barrier systems; separation of vehicles to prevent head-on crashes; and separation of vulnerable road users (e.g. dedicated cycle lanes; adequate footpaths for pedestrians). Other treatments provide safety benefits, but when used in isolation will leave a substantial residual in terms of deaths and serious injury. These 'supporting' treatments include signs, line-marking, and also traffic signals.

Other key findings included that:

- there is a greater need to share good practice in Safe System implementation
- there is a need to provide 'redundancy' or 'backup' systems when installing safety treatments in case there are failures in one or more components
- development of a clear functional road hierarchy for speed management purposes is crucial for the implementation of Safe System infrastructure
- risk assessment is still an important tool in the implementation of Safe System infrastructure and;
- the timeframe for implementation of Safe System infrastructure is an important consideration.

The findings from this workshop led to a program of research conducted on Safe System infrastructure, funded mostly by Austroads. This included research and guidance on:

- Local government and the Safe System [5]
- Speed limit setting within the Safe System context [6, 7, 8]
- Infrastructure/speed limit relationship in relation to road safety outcomes [9]
- Safe System and design for roadsides [10]
- Assessments to improve safety performance of key types of infrastructure (including signalised intersections, roundabouts and barrier systems [11]
- Asset management and the Safe System approach [12]
- Safe System as it applies to infrastructure planning [13]
- Implementing Safe System infrastructure in low and middle income countries [14]
- Feasibility and cost of moving towards a truly Safe System infrastructure [15, 16]

This research continues, with current projects assessing the level of Safe System alignment of intersection options as well as potential improvements; development of a Safe System infrastructure assessment framework; and further work on safety barriers. The work on Safe System infrastructure is assessing the fatal and serious crashes that remain, even when more effective infrastructure improvements are provided. Using the example of roundabouts, although a substantial proportion of fatal and serious injury crashes are eliminated, a number may still remain. Analysis of data on the remaining high severity crashes indicate that many of those who may continue to be killed or injured are either bicyclists or motorcyclists, and so current research is assessing improvements that can be made to address this residual severe injury problem. Similar research is being undertaken on other key types of road infrastructure.

The Safe System assessment framework is intended to assess infrastructure projects from the perspective of each Safe System pillar to determine likely safety outcomes. It also provides practitioner-level advice on appropriate improvements to minimise death and serious injury. A tool is being developed to allow simple assessments by practitioners; whether working with state or local government.

ARRB is working with CASR in South Australia to develop a 'Safe System Book' that provides direct and clear guidance to those designing and operating the road network. Austroads is revising national guidelines, including guidance on road safety, traffic management, road design, road tunnels and asset management to embed Safe System principles and practice.

Most recently, a symposium was attended by 35 leading road agency and academic experts to provide inputs into the Safe System Assessment Framework and practitioner guidance on Safe System infrastructure. The workshop explored current progress in implementing the Safe System approach as it relates to road infrastructure, gaps in knowledge and planned future activity. Further workshops are being held throughout 2015 to progress knowledge. The outputs from these events will be published in the near future, but key findings include better advice on treatment selection and design that will minimise death and serious injury for different road environments and users, as well as advice on a phased, cost-effective approach for the implementation of Safe System infrastructure.

Crash risk assessment

A major area of research has also been development of new processes to identify, assess and treat high risk locations on the road network. The traditional approach in road safety has been to identify such locations based on crash history. Addressing such 'blackspots' has proven to be of high benefit, and continues to produce high returns on investments (as identified above, the most recent federal evaluation showed benefits of 8:1 when compared to costs; BITRE, [2]). However, it is known that many of the sites easiest to treat have already been treated. The majority of severe crashes are now estimated to occur outside what would traditionally be classified as 'blackspots'. Conversely, a large proportion of more serious crashes occur at locations where there is no existing crash history [17]. As an example, in New Zealand 56% of fatal and serious crashes occur at locations on roads with no other injury crashes recorded in the previous five years [18]. In response to this issue, new tools have been developed to identify and treat risk locations, based on road design and traffic elements. Research has been conducted to determine the impact different design elements have on safety outcomes. For example, a straight road is safer than a road with a severe curve. International and local research has been reviewed to determine relationships between design elements and safety outcomes [19]. This information has been used to develop risk models that are able to predict the chances of high severity crashes occurring without the need for information on crash history. The data and approach identified through this research is now used nationally through the successful AusRAP program (http://www.aaa.asn.au/aaa-agenda/road-safety/) and has also formed the basis of the international approach to risk assessment (iRAP, see www.irap.org).

In areas where crashes are more dispersed (such as lower volume rural roads), a greater weighting is applied to the design elements as a predictor of serious injury

Most recently, the information on crash risk through assessment of road design has been combined with information on crash locations. This combined approach provides a powerful tool in the assessment of risk locations, and in the identification of effective treatments. To this end, the Australian National Risk Assessment Model (ANRAM) was developed and is now being used by most Australian jurisdictions, and is included in the National Road Safety Strategy and associated Action Plan as a key mechanism for prioritising investments in infrastructure. The model places a greater emphasis on crash history where information is more reliable (e.g. in higher traffic volume areas where crash trends are a more reliable indicator of future crash occurrence), while in areas where crashes are more dispersed (such as lower volume rural roads), a greater weighting is applied to the design elements as a predictor of serious injury. The approach provides greater reliability in predicting future high severity crash locations, as well as information on the solutions to address these crashes. Further information can be found in Jurewicz and Steinmetz [20], or on the ANRAM knowledge hub (http://www.arrb.com.au/Safe-Systems/Assessing-and-managing-road-crash-risk/ANRAM-Hub.aspx). An example of the successful application of this tool by a state road agency can be found in a study by Eveleigh et al. [21].

Effectiveness of road safety treatments (Crash Modification Factors)

Accurate knowledge on the effectiveness of road safety treatments is required to make informed decisions on road safety funding. It is only with sound information that the most appropriate safety treatment can be selected. Poor information can lead to treatments that will have little or no effect, thereby wasting valuable limited resources. One key element of this decision making process is the Crash Modification Factor (or CMF; sometimes termed a crash reduction factor, or CRF) for different remedial treatments. Research has involved the assessment of different evaluation studies to help identify appropriate CMFs for Australian conditions.

Tactile strips on line markings can provide audio warning to motorists

The most recent summary of this information can be found in Turner et al. [22]. This report includes information on the likely safety benefit of different commonly used treatments, as well as the level of confidence in this figure. An extract of this information can be seen in Figure 1.

Treatment	Environment type	Crash reduction factor	Crash modification factor	Confidence	Year most recently assessed	Reference location
Intersection treatments						
Signal visibility	Replace a pedestal mount with mast arm mount signal	35%	0.65	Low	2011/12	Appendix C.7
	Increase lens size to twelve inches	5%	0.95	Low	2011/12	Appendix C.7
	Provide additional signal head	20%	0.8	Medium	2011/12	Appendix C.7
Roundabouts	Install roundabout – rural	70%	0.3	High	2008/09	Austroads 2010a
	Install roundabout – urban	55%	0.45	Medium		Austroads 2010a
	Install roundabout – all environments	70% (all)	0.3 (all)	High		Austroads 2010a
		60% (pedestrians)	0.4 (pedestrians)	Low	2010/11	Appendix C.18.7

Source: [22]

Figure 1. Effectiveness of treatments - extract

The values in this report have been widely adopted by Australian road agencies as well as international bodies (including iRAP). Given one of ARRB's objectives is to provide relevant road safety tools to practitioners on infrastructure safety, the information on CMFs has also been included in a freely accessible website, the Road Safety Engineering Toolkit (engtoolkit.com.au; also see Jurewicz [23]). This provides advice on suitable measures to address road safety problems, including information on their benefits. An international version of this tool, intended for use by those in Low and Middle Income Countries has also been developed (the iRAP Road Safety Toolkit, available at http://toolkit.irap.org/; also see [24]).

This research has helped identify a number of key treatments which are only used to a limited extent in Australia. Greater use of such treatments has the potential to improve safety significantly. This program of work has also helped identify the gaps in understanding that currently exist on this issue. Individual studies have been undertaken to help fill some of these gaps. This has included recent evaluations on gateway treatments [25]; vehicle activated signs [26, 27]; speed limit change [28]; and centre-of-road wire rope barrier [29].

Recognising the significant gaps in knowledge regarding some of the most widely used treatments, as well as those showing promise, ARRB in association with the US Federal Highway Administration (FHWA) initiated an international collaboration through OECD/ITF to facilitate the sharing of information on this topic. This work identified a methodology for effective sharing of information [30] (also see Cairney, Turner and Steinmetz [31] for an Australian-centred examination of this issue). There are still significant areas of work required, particularly around the benefits in terms of fatal and serious injury reduction from road engineering treatments. This issue is discussed in further detail as follows.

Centre-of-road wire rope barrier

Speed/infrastructure relationship

Much of the research on road infrastructure includes consideration of other pillars of the Safe System approach. Infrastructure changes have the potential to impact on driver behaviour and indeed reduction in the likelihood of road user error through this mechanism is often the intention. Similarly, there is a strong link between speed management and road infrastructure. Ideally, all roads would form part of a clearly defined hierarchy that relate to the appropriate speed limit for the function of the road. The place within the hierarchy would be supported, and clearly communicated to road users through the design and features of that road.

Effective speed management, which includes speed limits and supporting infrastructure, has great potential for improving road safety outcomes. Speed is an element in all crashes; influencing both the likelihood and severity. In support of more effective speed management methods a number of projects have been undertaken. This has included the development of a process to integrate speed limit setting with infrastructure provision to help achieve Safe System outcomes [9]. The outcome of this work includes a process that recommends the assessment of the current road function and speed environment, a review of current road features and completion of a gap analysis. Model national guidance has been developed on implementing reduced speed limits on roads with high risk of severe crashes which cannot be reasonably treated with cost-effective engineering treatments [32]. Information has also been provided on some of the trade-offs between speed and other transport policy outcomes [33].

Along with existing guides on speed management for local roads from Austroads [34, 35], recent research and advice has centred on the approaches that may be taken to addressing speed at key points on rural roads [36]. A compendium has been produced, highlighting the speed issue on rural roads. Around 30 treatments have been provided that address 'unsafe speed' at locations such as curves, intersections, approaches to townships and along routes. Some highly effective treatments were identified and in some cases these are used rarely in Australia. Key treatments included:

- Consistent speed warning and design for curves (also see [37])
- Gateway treatments on the approach to townships (also see [25])
- Roundabouts at intersections
- Vehicle activated signs for curves and intersections (also see [26]) and;
- Speed limits combined with narrow centreline treatments for routes.

Current research is examining effective speed moderating treatments that can be applied to the urban arterial network [38]. This road type has now been identified as the leading location of death and serious injury in Australia [39]. Specific treatments include:

- greater use of roundabouts (including signalised roundabouts) at intersections
- raised road surface treatments at intersections (platforms; raised stop lines)
- raised midblock treatments
- raised treatments for pedestrians (i.e. Wombat crossings) and;
- 'road diets' on high volume routes (i.e. converting four lane roads to two lane, with a central turning lane).

Current research is examining effective speed moderating treatments that can be applied to the urban arterial network

Evaluations are currently being undertaken on several of these promising treatments to help improve knowledge on effectiveness.

Addressing key crash types and user groups

Another area of research has been the production of direct advice on the extent of key crash types, as well as the solutions that may be applied to address these crash types. This research has generally been based on key crash types that contribute most to fatal and serious crash outcomes. Although much of the guidance is on infrastructure solutions, other non-infrastructure options are also typically addressed to some extent. Examples include:

- Run-off-road crashes and roadside safety [40]
- Head-on crashes [41, 42]
- Intersection crashes [43]
- Rear end crashes [44]
- Fatigue-related crashes [45]
- Motorcycle crashes (in progress) and;
- Cyclist crashes at roundabouts (in progress).

Crash data and benchmarking

Integral to this research is the need for good quality data. In Australia, each jurisdiction collects its own crash data and historically only the fatal data has been recorded at Commonwealth level. This has presented a barrier to the comprehensive assessment of crash data. To the best of our knowledge, the first published study on all fatal and serious crashes from Australia was only released this year [39]. This study indicated that when analysing just these high severity crash outcomes, the key crash types for Australia involved vehicles ‘off-path’ (35% of fatal and serious casualties, involving road users running off the road); head-on (17%); adjacent approaches (i.e. intersection; 14%) and same direction (i.e. rear-end; 14%). The results also indicated that urban arterial roads were a key location for fatal and serious crashes, a markedly different result than when an analysis on just fatal crashes is conducted (note that the national strategy calls for reduction in fatal and serious casualties).

One advantage of obtaining this data from each Australian jurisdiction is the ability to benchmark performance between areas, regions or jurisdictions. The advantage of the approach is that it allows identification of areas and issues that might produce quick gains in safety improvements. For instance, if one area has high pedestrian risk when compared to another similar area, this might help identify a need for further investigation, and also ideas on effective solutions. This approach has been widely applied in Europe for a number of years. For example, the European Transport Safety Council regularly publishes a road safety Performance Index (or ‘PIN’, see http://etsc.eu/projects/pin/). However, the approach has not been widely applied in Australia. A current project with Austroads takes this approach, but also provides the basis for a comparison with key leading overseas jurisdictions. Measures of risk based on amount of travel undertaken gives a direct comparison for infrastructure safety performance. This involves a complex process of joining crash, traffic volume and asset data together (see Jurewicz and Bennett [46] for a description of an approach previously used). It should be feasible to compare how different road types in Australia compare to the leading countries (e.g. rural freeways in Australia compared with the Netherlands); or how the design of individual infrastructure elements might compare (e.g. rural roundabout in Australia compared with roundabouts in Sweden). Again, this approach is expected to identify areas where quick gains might be made, particularly through improvements in design of road infrastructure.

The data assembled through this work has had many additional uses, including as a platform for research for many of the studies identified above. This work has also highlighted the difficulties in collecting detailed crash data at national level, as well as differences in the way that data is collected in each jurisdiction. Unfortunately, funding for the collection of this detailed data is not certain, and so in-depth national analysis may not be possible in to the future.

Non-crash data is also of high importance for the effective management of road safety [47]. The link between intermediate measures and final outcomes (typically the crash data) is critical to help determine the effect of safety investments. From an infrastructure perspective, the non-crash data includes information on road and roadside design and management. This information has typically been collected in the past by asset managers, but in recent years this has been put to good use for the effective management of safe infrastructure. This approach has been used by AusRAP, iRAP and ANRAM to identify risk locations, and to develop business plans for future investments in road infrastructure. The data is also increasingly recognised for its ability to help monitor performance against key targets. The use of probe data (gathered from in-vehicle GPS, including mobile phones) is also proving useful as an intermediate measure, particularly in measuring speeds at points on the road, or across the road network.

Development of tools and dissemination

A key objective for ARRB and its member road agencies is to ‘package’ new and existing research and processes to help achieve better safety outcomes. Without dissemination of research findings and outcomes, the cost and effort of research is largely wasted. This has led to the development of tools for use by practitioners that package up research findings and good practice. These tools include:

- ANRAM (highlighted above) and similar crash risk assessment tools;
- Road Safety Engineering Toolkit (and iRAP Road Safety Toolkit; both highlighted above) that provide direct advice on safety problems and appropriate treatments;
- The Road Safety Audit Toolkit (http://www.rsatoolkit.com.au/) – designed to help step practitioners through the road safety audit process, and documentation of this;
- XLIMITS – a set of tools designed to assist in the appropriate assessment of roads for the purpose of speed limit setting (used in Australia, New Zealand and the United States) and;
- Guides, such as those produced by Austroads.

Much of the work undertaken is aimed at updating national guidelines, including improvement of processes and delivery. This includes recent research on crash costing (e.g. advice on willingness to pay [48, 49]; and treatment life [50]); and a study on ‘failed’ blackspots, or treated locations that do not meet their potential (in progress).

Guidance production and training are key dissemination mechanisms that are used to translate research outcomes into practice. Guidance documents primarily include the Austroads guides, including those on road safety (currently nine parts), traffic management, road design and road tunnels. All of these are available from the Austroads website (www.austroads.com.au). However, this guidance development also includes significant input to global guides, including those on speed management, drinking and driving, data systems, pedestrian safety, and motorcycle safety (see http://www.who.int/roadsafety/publications/en/).

Most recently, ARRB has been leading a team of international experts in the development of the World Road Association's (PIARC) Road Safety Manual. This document collects good practice from many countries around the world on effective management and delivery of Safe System infrastructure. It is expected to be the new global guide on safe roads and infrastructure, and will provide advice that will be directly relevant to those working on this issue in Australia, as well as elsewhere in the world.

Gaps in knowledge

Although an extensive amount of research has been undertaken over recent years, there is still a large amount to be done. Given the scale of the problem, and annual expenditure on roads, the price of poor knowledge on safety outcomes is significant. There are many gaps in knowledge that mean that cost-effective road safety decisions can be limited. The gaps relating to treatment effectiveness (CMFs) have already been mentioned. Without an improvement in this knowledge there will be poor decisions regarding the selection of effective road safety infrastructure countermeasures. This requires a concerted international effort to identify and fill gaps in knowledge. An international collaboration has commenced, but further steps are required to continue this work. A new phase of collaboration is planned (through the Forum of European National Highway Research Laboratories, which also includes ARRB and FHWA in the US). However, appropriate funding is required to ensure key objectives are met from this work, particularly those relating to specific Australian needs.

Although many effective infrastructure solutions are well known and used, there are some areas where knowledge is limited, or solutions do not yet exist to help meet Safe System objectives. One example includes the use of effective infrastructure treatments to help improve safety for vulnerable roads users, including cyclists, motorcyclists and pedestrians. The CMF research includes very little information on specific benefits of existing treatments for these vulnerable road users. It is also likely that existing treatments will need to be adapted, or new treatments devised to better address these road users, who are significant contributors to road trauma. Research has commenced, but greater efforts involving the international research community are required.

As further examples, current signalised intersection design is inherently unsafe and there is a need for direct guidance on issues such as roadside design, and rural intersections. Ongoing innovation in design will be required to address future needs, but this raises a number of issues, including a reluctance to install solutions that are not already part of design guidelines. Incentives and encouragement are required to help innovation, and find solutions that might effectively eliminate severe crash outcomes.

Similarly, there is a lack of information on the safety implications of different road design elements. Currently our knowledge base on several of these elements is severely limited, meaning that road construction decisions are not taking full account of safety. In some instances this might lead to significant increases in construction costs due to incorrect assumptions. One example, highlighted by Marsh [51] indicated that considerable savings to construction costs were made in Western Australia based on more accurate safety information relating to the benefits of roadside barriers. This led to reduced earthworks, and therefore substantially reduced costs, but with additional safety benefits.

There still appears to be a large amount of 'silo thinking' in road safety, and this has perhaps increased rather than decreased under the Safe System approach. Although various attempts have been made to capture and combine safety benefits across pillars, there is much to be done on this issue. As one example, the interaction between roads and emerging vehicle technologies need to be assessed. Several new technologies rely on road infrastructure to work most effectively. This includes lane departure systems, which typically monitor the vehicle's position in relation to a painted centre or median line. Further work is required to ensure potential safety benefits are maximised (as well as costs reduced) from such opportunities.

Lastly, there is currently a shrinking pool of funding to address the issue of road safety infrastructure research. Given the expenditure on construction, maintenance and operation of roads, it is likely that any further reduction in this spending will have a significantly adverse effect on efficient delivery of safe roads and infrastructure. Conversely, increased spending will most likely produce significant benefits for road agencies and the broader community.

Concluding comments

The last decade has seen some substantial changes in the way that safe road infrastructure is delivered. The Safe System approach has meant new ways of analysing and addressing safety problems. The approaches used to assess risk and select locations for treatment are evolving. New 'hybrid' methods that combine crash history with knowledge of design features and their likely safety outcomes are being used to better predict future high severity crash locations. The solutions are being applied in more systemic ways, aided by a new generation of tools such as ANRAM.

Although there is improved information on effective infrastructure treatments, the knowledge base is still deficient. There are gaps in knowledge on ways to address some key crash problems. Some new or existing treatments that show great promise should be used more extensively. There is also a need to refine existing treatments, and develop new infrastructure solutions that will eliminate death and serious injury for different road environments and users.

Greater synergies are being developed between safety and other key aspects of transport policy and management, including asset management, and travel demand/transport planning. It will be important to expand these linkages to better capture safety benefits within these areas, especially in light of limited budgets specifically for safety.

Given the substantial investment in roads, a small improvement in delivery to direct efforts towards more effective safety outcomes is likely to produce significant benefits. Better knowledge and more effective use of existing knowledge are required to meet this objective. Road agencies, particularly through Austroads, have provided funding for safe road and infrastructure research over recent years. However, with road agencies needing to work smarter with reduced budgets and some significant knowledge gaps in delivering safe infrastructure, there is a need to renew efforts to find better ways to deliver safer roads.

Acknowledgements

The author would to like thank Michael Tziotis, Chris Jurewicz and David McTiernan from ARRB for comments provided on an earlier draft, as well as Adrian Papamiltiades for help in formatting the paper. The contributions from Austroads, who funded much of the research described in this paper is also gratefully acknowledged.

References

1. Stigson, H Krafft, M & Tingvall, C. Use of Fatal Real-Life Crashes to Analyze a Safe Road Transport System Model, Including the Road User, the Vehicle, and the Road. Traffic Injury Prevention, 9:5, 2008, 463 – 471.
2. BITRE. Evaluation of the National Black Spot Program, Bureau of Infrastructure, Transport and Regional Economics, Canberra, Australia, 2012.
3. Austroads 2015, http://www.austroads.com.au/about-austroads/about-austroads, viewed 1 June 2015.
4. Turner, B, Tziotis, M, Cairney, P & Jurewicz, C. Safe System Infrastructure – National Roundtable Report, Research Report ARR 370, ARRB Group Ltd, Vermont South, Australia, 2009.
5. McTiernan, D Turner, B Wernham, R & Gregory, R. Local government and the Safe System approach to road safety. ARRB Group Ltd, Vermont South, Australia, 2010.
6. Jurewicz, C & Hall, K, Speed limit setting principles in the safe system context, Australasian Road Safety Research Policing Education Conference 2009, Sydney, New South Wales, Australia, 2009.
7. Jurewicz, C. Speed limits in the safe system concept, Journal of the Australasian College of Road Safety, vol 21 no 2, 2010, 14-7.
8. Jurewicz, C & Turner, B. Risk-based approach to speed limits: a step towards Safe System, Australasian College of Road Safety Conference, Melbourne, Victoria, Australia, 2011.
9. Jurewicz, C & Turner, B. Infrastructure/speed limit relationship in relation to road safety outcomes, Report AP-T141/10, Austroads, Sydney, New South Wales, Australia, 2010.
10. Jurewicz C & Troutbeck, R. A safe system based approach to selection of clear zones, safety barriers and other roadside treatments, Australasian Road Safety Research Policing Education Conference, Wellington, New Zealand, 2012.
11. Jurewicz, C, Pratt, K & Makwasha, T. Improving the performance of safe system infrastructure: stage 1 interim report, Report AP-T256/13, Austroads, Sydney, New South Wales, Australia, 2013.
12. Toole, T, Kelley, J & Turner, B. Asset management within a safe system, Report AP-R442/13, Austroads, Sydney, New South Wales, Australia, 2013.
13. Steinmetz, L, Jurewicz, C & Taylor, S, pending, Safe System in the Planning Process, Austroads, Sydney, Australia.
14. Turner B & Smith G. Safe System Infrastructure: Implementation Issues in Low and Middle Income Countries. Research Report ARR 383, ARRB Group Ltd, Vermont South, Australia, 2013.
15. Roberts, P. Using driver errors to inform safe system infrastructure development, ARRB Conference, 26th, 2014, Sydney, New South Wales, Australia, 2014.
16. Roberts, P, Woolley, J & Doeke, S. Providing for road user error in the safe system, Report AP-R460/14, Austroads, Sydney, New South Wales, Australia, 2014.
17. Roper, P & Turner, B. Why do we need to take a risk assessment based approach in road safety? ARRB Conference, 23rd Adelaide, South Australia, Australia, 2008.
18. NZ Transport Agency. High-risk intersections guide, NZTA, Wellington, New Zealand, 2013.
19. Jurewicz, C Aumann, P, Bradshaw, C, Beesley, R & Lim, A. Road Geometry Study for Improved Rural Safety, Report AP-T295/14, Austroads, Sydney, New South Wales, Australia, 2015.
20. Jurewicz, C, Steinmetz, L, & Turner, B. Australian National Risk Assessment Model, Report AP-R451/14, Austroads, Sydney, New South Wales, Australia, 2014.
21. Eveleigh, M., Abeysekera, R., Tang, J. Investigation into the Application of the Australian National Risk Assessment Model (ANRAM) to a Route Safety Review. The Road Safety, Research, Policing & Education Conference, Melbourne, Australia, 2014.
22. Turner, B, Steinmetz, L, Lim, A & Walsh, K. Effectiveness of Road Safety Engineering Treatments, AP-R422-12, Austroads, Sydney, Australia, 2012.
23. Jurewicz, C, Road safety engineering toolkit, Australasian Road Safety Research Policing Education Conference 2007, Melbourne, Victoria, Australia, 2007.
24. Smith, G, Turner, B & Hill, J. A toolkit for saving lives, Journal of the Australasian College of Road Safety, Vol 22, No 2, 2011, 18-23.

25. Makwasha, T & Turner, B. Evaluating the use of rural-urban gateway treatments in New Zealand, Proceedings of the 2013 Australasian Road Safety Research, Policing & Education Conference, 28th – 30th August, Brisbane, Queensland, 2013.

26. Makwasha, T & Turner, B. Evaluating vehicle activated signs on rural roads, ARRB Conference, 26th, 2014, Sydney, New South Wales, Australia, 2014.

27. Bradshaw, C, Bui, B & Jurewicz, C. Vehicle activated signs: an emerging treatment at high risk rural intersections, Australasian Road Safety Research Policing Education Conference 2013, Brisbane, Queensland, Australia, 2013.

28. Pyta, V, Pratt, K & Bradbrook, D. Evaluation of Peninsula SaferSpeeds: speed limit reduction and community perceptions, ARRB Conference, 26th, Sydney, New South Wales, Australia, 2014.

29. McTiernan, D, Thoresen, T & McDonald, N. Evaluation of the safety impact of centre-of-the-road wire rope barrier (WRB) on undivided rural roads, AP-T135-09, Austroads, Sydney, Australia, 2009.

30. OECD. Sharing Road Safety, Organisation for Economic Co-operation and Development (OECD), Paris, France, 2012.

31. Cairney, P, Turner, B & Steinmetz, L. An introductory guide for evaluating effectiveness of road safety treatments, AP-R421-12, Austroads, Sydney, Australia, 2012.

32. Jurewicz, C, Phillips, C & Tziotis, M. Model national guidelines for setting speed limits at high-risk locations, AP-R455-14, Austroads, Sydney, Australia, 2014.

33. Jurewicz, C. Impact of lower speed limits for road safety on network operations, AP-T143-10, Austroads, Sydney, Australia, 2010.

34. Damen, P, Brindle, R, & Gan, C. Guide to traffic management: part 8: local area traffic management, AGTM08-08, Austroads, Sydney, Australia, 2008.

35. Jurewicz, C. Impact of LATM treatments on speed and safety, AP-T123-09, Austroads, Sydney, Australia, 2009.

36. Turner, B & Makwasha, T. Methods for reducing speeds on rural roads: compendium of good practice, AP-R449-14, Austroads, Sydney, Australia, 2014.

37. Jurewicz, C, Chau, T, Mihailidis, P & Bui, B. From research to practice: development of rural mass curve treatment program, Australasian Road Safety Research Policing Education Conference, 2014, Melbourne, Victoria, Australia, 2014.

38. Turner, B, Makwasha, T & Pratt, K. Methods for reducing speeds on urban arterial roads, Australasian Road Safety Research Policing Education Conference, 2014, Melbourne, Victoria, Australia, 2014.

39. Bradshaw, C, Turner, B, Makwasha, T & Cairney, C. Road fatalities and serious injuries in Australia and New Zealand 2001-10, AP-R478-15, Austroads, Sydney, Australia, 2015.

40. Jurewicz, C, Steinmetz, L, Phillips, C, Cairney, P, Veith, G & McLean, J. Improving roadside safety: summary report, AP-R437-14, Austroads, Sydney, Australia, 2014.

41. Tziotis, M, Styles, T & Turner, B. Road safety engineering risk assessment part 8: rural head-on crashes, AP-T153-10, Austroads, Sydney, Australia, 2010.

42. Beck, D. Investigation of key crash types: run-off-road and head-on crashes in urban areas: final report, AP-R450-14, Austroads, Sydney, Australia, 2014.

43. Tziotis, M, Turner, B & Styles, T. Road safety engineering risk assessment, part 9: rural intersection crashes, AP-T154-10, Austroads, Sydney, Australia, 2010.

44. Beck, D. Investigation of key crash types: rear-end crashes in urban and rural environments, AP-R480-15, Austroads, Sydney, Australia, 2015.

45. Roberts, P, Rodwell, L & Harris, K. Innovative road safety measures to address fatigue: review of research and results from a treatment trial, AP-R379-11, Austroads, Sydney, Australia, 2011.

46. Jurewicz, C & Bennett, P. Road safety engineering risk assessment: part 7: crash rates database, AP-T152-10, Austroads, Sydney, Australia, 2010.

47. WHO. Data systems: a road safety manual for decision-makers and practitioners, World Health Organization, Geneva, Switzerland, 2010.

48. Naude, C, Tsolakis, D, Tan, & Makwasha, T. Social costs of road crashes in Australia: the case for willingness-to-pay values for road safety, AP-R438-15, Austroads, Sydney, Australia, 2015.

49. Tsolakis, D, Turner, B, Perovic, J & Naude, C. Component costs in transport projects to ensure the appropriate valuing of safety effects, AP-T125-09, Austroads, Sydney, Australia, 2009.

50. Turner B and Comport L. Road safety engineering risk assessment part 4: treatment life for road safety measures. Austroads, Sydney, Australia, 2010.

51. Marsh, B. Towards Zero Road Planning, Design and Construction, 25th ARRB Conference – Shaping the future: Linking policy, research and outcomes, Perth, Australia, 2012.

Adopting the 3-Star minimum safety rating

by Greg Smith
International Road Assessment Programme (iRAP), Regional Director, Asia Pacific,
Registered office: 60 Trafalgar Square, London, WC2N 5DS.

The world is poised to adopt a *Sustainable Development Goal* committing to halve road deaths by 2030. Achieving that goal means that all countries will need to apply known solutions much more systematically than previously to achieve safer roads, vehicles and behaviour. This is especially the case in developing countries that are now investing heavily to overcome a lack of basic infrastructure, including providing for the nearly one billion people in rural areas that lack access to all-weather roads [1].

Consistent with the 'safe system' approach, countries leading in road safety are increasingly examining ways to ensure that people do not come to serious harm on their networks. The use of star rating targets is becoming more prevalent as a mechanism for managing safety on major roads and guiding investment. Highways England, a newly established government corporation for national roads, has a goal that 90% of travel on its network will be at 3-star or above by 2020. The Netherlands is now within 25km of achieving its 3-star target for national roads. Sweden's administration aims for better than 75% by 2020 and near 100% by 2025. New Zealand has completed a review of design standards to ensure that Roads of National Significance (RoNS) will be implemented with a minimum 4-star KiwiRAP rating. In Australia, the Australian and Tasmanian Governments have released a 10-year, $500 million action plan to improve the Midland Highway to at least 3-stars.

There is good evidence that better star ratings are associated with lower crash costs. Most recently, the Road Safety Foundation reported that re-surfacing, improvement of road markings, lowering the speed limit, and improvement of pedestrian crossings on a stretch where pedestrians were especially vulnerable allowed a section of the A404 in Buckinghamshire, UK, to rise from 2-stars to 3-stars overall and this helped cut crashes by 90% [2]. A study on the Bruce Highway in Queensland, found that: crash costs on 2-star roads are 40% lower than on 1-star roads; crash costs on 3-star roads are 61% lower than on 2-star roads; and crash costs on 4-star roads are 43% lower than on 3-star roads (see Figure 1) [3].

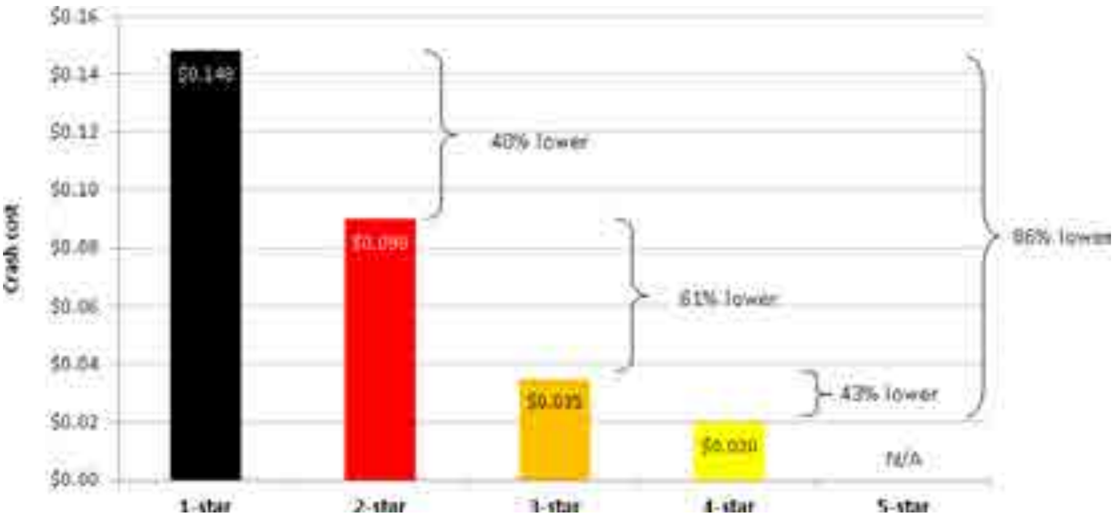


Figure 1. Smoothed vehicle occupant Star Ratings and fatal and serious injury crash costs per vehicle kilometre travelled

Star rating targets are also being taken up by developing countries, where the large majority of the road trauma burden lies. The World Health Organization (WHO) estimates that around 800,000 people are killed in road crashes in the Asia Pacific region each year, accounting for 65% of global road deaths [4]. Roads in this region have alarmingly high rates of trauma and extremely high rates on particular stretches. As just one example, crash scene investigations conducted as part of iRAP assessments on a 53km stretch in Karnataka, India recorded nine deaths and 17 serious injuries during a period of just 45 days [5]. That equates to an annualised death rate of 1.4 deaths per km, around 20 times higher than the average annual death rate on the Lapstone to Katoomba section of the Great Western Highway in NSW, which was identified by AusRAP as a particularly high-risk section of Australian national highway network [6].

The impact of serious road crashes on individuals and families is well documented. A high proportion of households report 'catastrophic expenditure' following a road death or injury [7]. After a serious crash, households often need to borrow money, sell an asset, give up study or take on extra work just to survive. We estimate that across Asia Pacific, road deaths and serious injuries cost US $820 billion per year, or about 4% of Gross Domestic Product (GDP) [8].

The iRAP assessments, which involve road surveys and recording road attribute details for each 100 metre segment of a road, are helping to explain why levels of trauma can be so high in the Asia Pacific region [9]. Roads where billions of kilometres of travel occur each year often have fundamentally unsafe designs (see Figure 1). It is common for roads that carry significant pedestrian and bicycle flows to have no footpaths and bicycle paths. Dedicated motorcycle lanes in countries like Vietnam, where the majority of vehicles are motorcycles, are uncommon. Roadside hazards are common, intersections often lack basic safety elements and roads that carry relatively high-speed traffic often do not have any median separation. Problems with safety are not limited to old roads – newly built roads often have risk built-in. For example, despite the International Road Federation (IRF) recommending that "road authorities in all countries immediately prohibit new installations of 'Fishtail' or 'Spoon' terminals…", these hazardous design safety barrier ends are still included in design standards in numerous countries and continue to be installed on upgraded and new roads [10]. This type of problem is often compounded by the fact that new, smoother pavements invariably lead to higher speeds that significantly increase risk unless ameliorated with safety countermeasures.

Figure 2. Key road attributes for a sample of 30,000km of roads in 11 low-income and middle-income countries in the Asia Pacific region

The iRAP star ratings are based on road inspection data and provide a simple and objective measure of the level of safety which is 'built-in' to the road for vehicle occupants, motorcyclists, bicyclists and pedestrians. Five-star roads are the safest while one-star roads are the least safe. Importantly, Star Ratings can be completed without reference to detailed crash data, which is often unavailable in low-income and middle-income countries. Figure 3 illustrates star ratings for roads in the Asia Pacific region, and lists road attributes that influenced the ratings.

In China and India, which the WHO estimates account for a combined 40% of global road deaths, iRAP is working closely with governments and development banks to develop a long-term, large-scale approach to infrastructure safety. The China Road Assessment Program (RAP) team, a partnership between iRAP and the Ministry of Transport Research Institute of Highway (RIOH), is using star ratings to promote practical, localised road safety improvements. As just one example, the ChinaRAP team helped local road designers to almost double the percentage of road rated 3-stars or better in the US $400 million Asian Development Bank (ADB)-financed Shaanxi Mountain Road Safety Demonstration project [11]. It is estimated that the targeted use of roadside safety barriers, paved shoulders, realignments, enhanced skid resistance, traffic calming and pedestrian crossings will reduce deaths and serious injuries by 25%. The ChinaRAP team is now rolling out large-scale assessments across 12 provinces as part of the national "Highway Safety to Cherish Life" project. In its first 10 years, the program invested some US $5 billion in safety facilities on 366,000km of roads.

Figure 3a. Examples of roads and star ratings in Asia Pacific

Figure 3b. Examples of roads and star ratings in Asia Pacific

Figure 3c. Examples of roads and star ratings in Asia Pacific

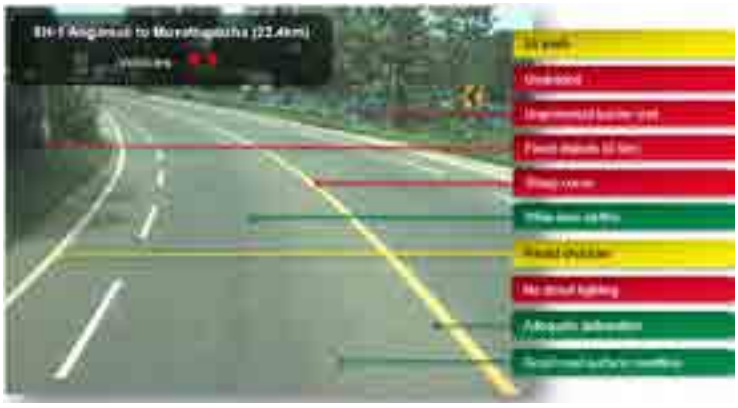


Figure 3d. Examples of roads and star ratings in Asia Pacific

Figure 4. Targeted improvements to designs in Shaanxi, China

During the past five years, iRAP has also worked in India with the Ministry of Road Transport and Highways (MoRTH), public works departments, research institutes, local engineering firms and motoring clubs to assess risk on more than 10,000km roads in Andhra Pradesh, Assam, Gujarat, Haryana, Karnataka, Kerala, Rajasthan, Tamil Nadu, Telangana and Uttar Pradesh. It is estimated that almost 60 million people live within three kilometres of these roads, and that as many as 75,000 deaths and serious injuries occur on the roads each year.

The iRAP investment plans have helped to make solutions to the enormous safety challenge in India clearer. It was estimated, for example, that by giving people a safe place to walk for instance, new footpaths on 440km of roads in Kerala could prevent 4,600 deaths and serious injuries over 20 years and save INR 3.4 billion (USD $55 million) in crash costs. Much of this cost would otherwise be borne by an already stretched health sector.

Importantly, investments to improve many of the roads have already been locked in. The iRAP assessments are now being used in World Bank-financed projects worth more than USD 5.3 billion, and many of these projects now specify targets for improved Star Ratings. For example, in the Second Karnataka State Highway Improvement Project (KSHIP) the government specified that demonstration corridors shall achieve a minimum of 3-stars for safety. In the Second Kerala State Transport Project, safety countermeasures that improve star ratings particularly for vulnerable road users have been written into designs (see Table 1). To date, designs for around 25% of the roads assessed across India have been star rated; helping to ensure that safety is built-in to the plans prior to construction. At the same time, hundreds of local engineers have taken part in training on the use of iRAP tools and road infrastructure safety.

Table 1. Safety countermeasures in the World Bank financed Kerala State Transport Project II (KRSP-II)

Item	Kasargod - Kanjangad	Pilathara – Pappinesserry	Thalaserry - Valavupara	Chenganoor – Ettumannoor	Ettumannoor - Muvattupuzha
Signalised junctions	9	4	8	12	2
Pedestrian crossings	24 table top 35 at-grade	14 table top 26 at-grade	26 table top 38 at-grade	36 table top 70 at-grade	30 table top 108 at-grade
Sidewalk	20.5km	22.9km	78.4km	77.8km	57.8km
Parking areas / ox-bow land development	12 parking areas 4 oxbow land	3 parking areas 4 oxbow land	1 parking area 27 oxbow land	13 parking areas 1 oxbow land	8 parking areas 1 oxbow land
Length of barriers	1.2km crash barriers 5.8km hand rails	3.5km crash barriers 5.4km hand rails	2.8km crash barriers 7.9km hand rails	5.9km crash barriers 15.4km hand rails	13km crash barriers 8km hand rails
Slow traffic segregation	13.2km	19.6km	77.9km	79.1km	78.1km

However, there remains an urgent need to scale up road safety efforts. In India for example, the Planning Commission foresees that 66,000km of new roads will be built at a rate of 30km per day. US $32 billion will be invested in 2015-16 alone [12]. It is crucially important that new investment, not just in India, but globally, is not simply geared towards accommodating larger volumes of faster moving traffic, but that it is effective at improving safety for the billions of people of who drive, ride and walk on roads each year. To help accelerate investment in safety, the Asian Development Bank (ADB) has floated wide use of iRAP star rating targets in development projects, suggesting:

1. all new or rehabilitation road designs should always have a higher safety rating than the existing road and have at least a 3-star rating standard for all road users
2. roads with more than 50,000 vehicles per day should have a minimum of 4-stars for all users
3. roads or sections of roads passing through linear settlements should have a minimum 4-star standard for pedestrians and cyclists [13].

The Africa Transport Policy Program, which is hosted by the World Bank, has similarly explored the potential benefits of setting a target of at least 3-stars for all road users [14]. In the United States of America, a coalition that includes the Institute of Transportation Engineers (ITE), AAA, the Insurance Institute for Highway Safety (IIHS) and American Society of Civil Engineers (ASCE) is advocating for roads in developing countries to be built to a minimum 3-star safety standard for all road users [15].

The moral and economic case for scaling-up investment in safe infrastructure is compelling. As we approach the Second Global High-Level Conference on Road Safety, we have an unprecedented opportunity to build on the growing momentum; to tackle the road crash epidemic; and leave a legacy of safe travel for future generations.

References

1. https://openknowledge.worldbank.org/handle/10986/20093.
2. http://www.roadsafetyfoundation.org/media/32555/star-rating-roads-for-in-built-safety.pdf.
3. http://irap.org/en/about-irap-3/research-and-technical-papers?download=91:relationship-between-star-ratings-and-crash-costs-the-bruce-highway-australia
4. http://www.who.int/violence_injury_prevention/road_safety_status/2013/en/
5. http://irap.org/en/about-irap-3/research-and-technical-papers?download=55:baseline-data-collection-in-india-karnataka-phase
6. http://www.aaa.asn.au/storage/AusRAP-report-2011-How-Safe-Are-Our-Roads.pdf
7. See for example: Nguyen, H et al (2015) Catastrophic household costs due to injury in Vietnam.
8. http://irap.org/en/about-irap-2/a-business-case-for-safer-roads
9. Specifications are available at: http://irap.org/en/about-irap-3/specifications
10. https://www.irfnews.org/docs/committees/IRF-ENDORSEMENT-TURNED_DOWN_ENDS-Resolution-110323.pdf
11. http://adb.org/projects/details?proj_id=46042-002&page=overview
12. Planning Commission (Government of India): Twelfth Five Year Plan (2012–2017) Faster, More Inclusive and Sustainable Growth
13. http://www.adb.org/sites/default/files/publication/31198/sdwp-031.pdf.
14. https://www.ssatp.org/sites/ssatp/files/publications/SSATPWP101-Road-Safety-Framework.pdf
15. http://www.fundforglobalhealth.org/join-the-3-star-coalition/

Developing a curve risk prediction model for a safe system signature project

by Paul Durdin[1] and Dale Harris[2]

1. Director, Abley Transportation Consultants Limited, paul.durdin@abley.com
2. Senior GIS Road Safety Analyst, Abley Transportation Consultants Limited, dale.harris@abley.com

This paper was presented at the IPENZ Transportation Group Conference, Rydges Hotel, Christchurch, 22-24 March, 2015. An update on future progress is planned for presentation at the ARSC 2015 conference at the Gold Coast, 14-16 October 2015.

Abstract

The Safer Journeys Action Plan 2013-2015 identifies safe system signature projects as a strategic action to achieve the Safer Journeys vision. The rural roads of New Zealand's Eastern Bay of Plenty (EBoP) region were identified as an area where a signature project has the potential to make demonstrable advances in reducing road trauma for all road users.

This paper describes a new risk prediction methodology that identifies high-risk curves independent of crash history. Using geospatial data and innovative analysis techniques, existing methodologies for identifying curves and calculating vehicle operating speeds were modelled and automated to undertake a network-wide assessment of high risk curves.

The new methodology extracted and classified almost 7000 curves across 1,500km of road network. When compared to the location of loss-of-control crashes, it was found that 66.6% of crashes occurred on 20.3% of curves classified as 'high risk' in at least one direction. These results have been shared with road controlling authorities and will support prioritised road safety improvements targeting high risk curves.

This methodology is the first network screening tool that has been specifically developed to address road safety risk in low volume rural areas. The methodology demonstrates how existing research into vehicle operating speed behaviour can be applied to identify high risk road elements and support targeted improvements that have the potential to significantly reduce road safety risk.

Introduction

Safer Journeys, New Zealand's Road Safety Strategy 2010-20 has a vision to provide a safe road system increasingly free of death and serious injury [4]. The strategy is founded on the safe system approach to road safety, which focusses on creating safe roads, safe speeds, safe vehicles and safe road use.

The Safe System philosophy is based on creating a forgiving road system that acknowledges that people make mistakes and have limited ability to withstand crash forces without being killed or seriously injured. Under the Safe System, all parts of the system - roads and roadsides, speeds, vehicles, and road use, all need to be improved and strengthened - so that if one part fails, other parts will still protect people involved in a crash.

Safer Journeys signifies a shift in focus, from reducing crashes to minimising the likelihood of high-severity crash outcomes. In order to give effect to Safer Journeys, new analytical approaches have been developed that prioritise sites on the likelihood of future fatal and serious casualty occurrence and risk.

Safe system signature projects are identified in the Safer Journeys Action Plan 2013-2015 [6] as exemplar projects that adopt a complete safe system approach to road safety. Safe systems signature projects provide a platform for trialling innovative approaches and treatments across the four safe system pillars.

Identifying the need

The Eastern Bay of Plenty (EBoP) region (Figure 1) was identified as a candidate for a safe systems signature project as it is a region with significant rural road safety issues; particularly speed, use of alcohol/drugs, poor restraint use and inexperienced drivers. Most EBoP roads are low volume remote roads with a very high proportion of rural road crashes occurring on curves - 57.9% of all fatal and serious rural road crashes 2004-2013 [8].

Due to the remote nature of the region's roads, fatal and serious crashes tend to occur sporadically on parts of the network where high-severity crashes have not occurred in the recent past. In these areas, relying on crash history alone is not a robust method of predicting where future crashes are likely to occur. Because of this, a new methodology that could assess and identify all high-risk curves on the network independent of crash history was required.

Existing methodologies, including Urban KiwiRAP [2] and the predictive risk models presented in the New Zealand

Figure 1. Eastern Bay of Plenty locality map

Transport Agency's Economic Evaluation Manual, are useful for highlighting safety issues along corridors and at intersections, but they do not identify the risk of individual geometric elements of the road's design that may be a contributing factor for these types of crashes. Similarly, the Star Rating of roads produced following iRAP protocols provides a strong basis for assessing the underlying safety of a section of road based on built features. However, calculation of Star Rating is manually intensive and is carried out on selected corridors – not an entire network.

Austroads operating speed model

The Austroads (2009) operating speed model for rural roads provides a procedure for calculating speeds along road sections based on the geometric features of the road, taking into account the typical behaviour of drivers and vehicles on higher speed rural roads. Using road geometry, the speed model includes figures for modelling acceleration along straights, deceleration through curves, and the identification of curve design limits based on approach speeds and curve radii.

The Austroads model is used by road designers to estimate operating speeds on relatively short, discrete corridors of highway. The model requires designers to assess the overall terrain and curvature class of the corridor, identify all the curves (including curve radii) and measure the distance between them. Corridors must be manually divided into discrete operating speed sections with minimum and maximum operating speeds. Speed behaviour is modelled in both directions as either:

- Acceleration on straights, or curves where the approach speed is less than the operating speed.

- Speed maintenance on straights less than 200m, or where approach speeds fell within operating speed ranges.
- Deceleration on curves where the approach speed is higher than the operating speed.

The Austroads methodology includes figures for modelling acceleration based on the length of straight and the initial speed, and deceleration based on the curve approach speed and curve radius. The model requires users to manually read these figures, calculating the exit speeds for each curve or straight which is then the approach speed for the following element.

One of the outputs of the Austroads methodology is the identification of design limits for curves, which can be used as a proxy for curve risk when considered in conjunction with the approach speed. Curves are classified as one of the following, in ascending order of risk:

- Within limit (a driver could safely accelerate through this curve)
- Desirable
- Undesirable
- Unacceptable

With 1,500 km of rural road, manually assessing the risk of each curve in the EBoP region using the Austroads model would be time-consuming and cost-prohibitive. As the inputs to the Austroads operating speed model are available in a spatial format, the model was therefore automated using a new Geographic Information Systems (GIS) methodology. This included the development of GIS models that identify curves, predict vehicle operating speeds along road corridors, and assess curve risk using approach speeds and radius.

Automating the operating speed model

Data requirements

The analysis relied on a number of road and environmental datasets. The most important dataset was a high-quality road centreline sourced from a third-party data supplier. This dataset closely represented actual road alignment and could be used to accurately identify curves and calculate curve radii.

Other road datasets, including Road Assessment and Management (RAMM), were used to extract road characteristics including surface type, carriageway width and ADT. A digital elevation model (DEM) with 15 metre resolution from the University of Otago - National School of Surveying [9] was used to extract terrain using advanced analysis in GIS. Crash data from the Crash Analysis System (CAS) was used for risk mapping and speed model validation [8].

Data preparation

The first step in preparing the data for speed modelling was extracting the rural roads and identifying unique corridors that replicated unimpeded travel along a road corridor. Corridors could only be 'broken' where vehicles would be required to slow or stop at an intersection, or meet an urban boundary. The start speed for each road corridor was then estimated according to the start context (Table 1).

Table 1. Corridor start speeds by context

Corridor start context	Start speed
Intersection	20 km/h
Road end	20 km/h
Urban boundary	50 km/h
Outside the study area	Maximum speed (refer Table 2)

The maximum speed on any road was calculated as a function of curvature and terrain (Table 2). These values are based on the desired speeds in Austroads 2009 [1] – the maximum speed regarded as acceptable to most drivers for the particular environment.

Table 2. Maximum (desired) speed by curvature and terrain

		Terrain (and grade %)			
Curvature		**Flat** (< 2%)	**Undulating** (2-4%)	**Hilly** (5-7%)	**Mountainous** (>=8%)
	Straight	110 km/h	110 km/h	95 km/h	90 km/h
	Curved	110 km/h	100 km/h	95 km/h	90 km/h
	Winding	90 km/h	90 km/h	85 km/h	80 km/h
	Tortuous	75 km/h	75 km/h	75 km/h	70 km/h

Curvature data, measured as degrees of turn per kilometre, was provided by the Transport Agency with the centreline dataset. Terrain (flat, undulating, hilly, mountainous) was calculated using geospatial analysis and the digital elevation model. For each 10m of road, raw grade was calculated over 100m and an average grade calculated over 1000m.

Curve identification

Curves were identified by adapting the methodology in Cenek et al. [3]. Using GIS linear referencing tools, the road centreline was divided into 10m sections and the rolling 30m average radius calculated for each arc section, as demonstrated in Figure 2.

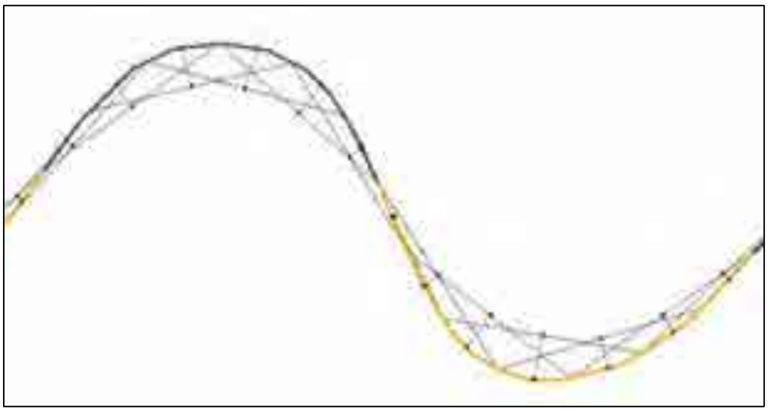


Figure 2: Example of curvature calculation

Discrete curve sections were extracted by combining road segments where:

- the radius was less than 800m;
- at least one 10m section had a radius of 500m or less; and
- the apex (direction) of the curve did not change.

Contiguous 10m sections of road that met these criteria were dissolved into a single curved segment, with the radius (m) of the curve defined as the minimum radius across all the sections that make up the curve.

Speed modelling

The Austroads 2009 guide [1] operating speed model predicts the operating (85th percentile) speed of cars travelling in each direction along a section of rural road. The model mimics the real-world behaviour of drivers based on a large number of car vehicle observations. As such, the model only applies to cars and cannot be used to predict the operating speeds of other types of vehicle.

Once curves had been identified (see above), each road corridor was divided sequentially into a series of curves with known radii, and straights with known lengths. Speeds were then modelled along the road centreline in both directions.

Sections of road with curves of a similar radius separated by short straights (less than or equal to 200m) were identified as discrete sections with an operating speed identified within a narrow range of values (minimum and maximum operating speeds). When drivers travel through a series of curves with similar radii, their speeds stabilise to a level they feel comfortable with [1]. Section operating speeds for single, isolated curves were also calculated.

Working along the road corridor, speed behaviour was modelled as either:

- *Acceleration* – on straights longer than 200m, or on curves where the approach speed is less than the operating speed of the curve.
- *Speed maintenance* – on straights less than 200m, or where the speed falls within the section operating speed range.
- *Deceleration* – on curves where the approach speed is higher than the operating speed for the curve (or series of curves).

Rates of acceleration and deceleration were modelled using the methodology in Austroads 2009 [1] (Figures 4 and 5). Extrapolation of values was required to estimate some acceleration and deceleration outputs, including acceleration for straights longer than 1000m (Figure 3) and deceleration where curve approach speeds are less than 60 km/h (Figure 4).

The exit speed at the end of each curve or straight is applied as the approach speed for the following section of road. For each curve where deceleration is modelled, the design limit is identified as either out-of-context (unacceptable or undesirable) or within context (desirable) (Figure 4). Curves where no deceleration is modelled are also considered to be ‘within limit’.

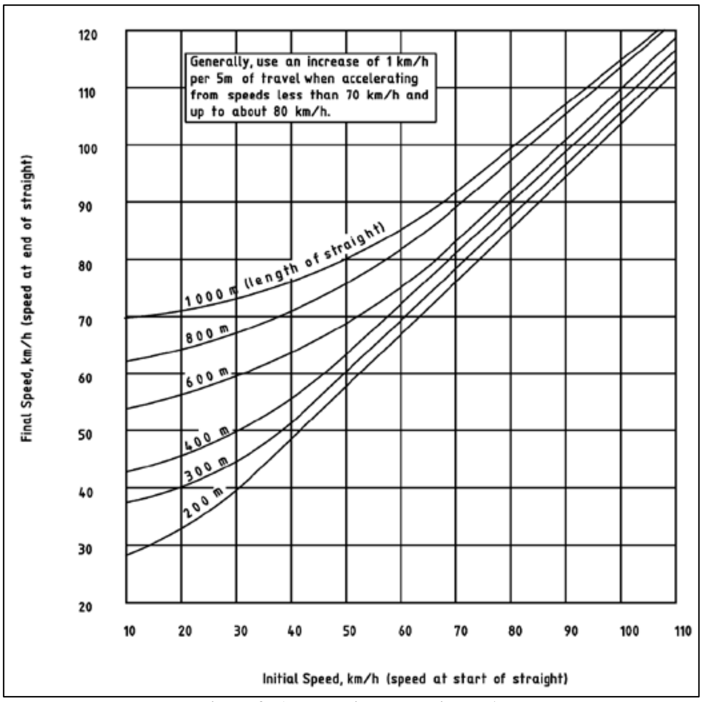


Figure 3: Acceleration on straights [1]

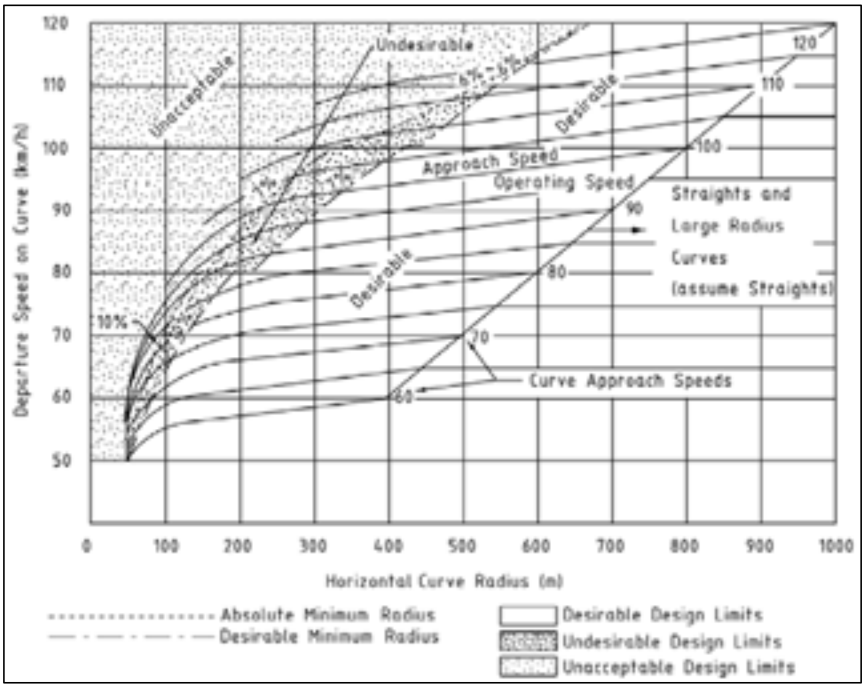


Figure 4: Deceleration on curves and design limits [1]

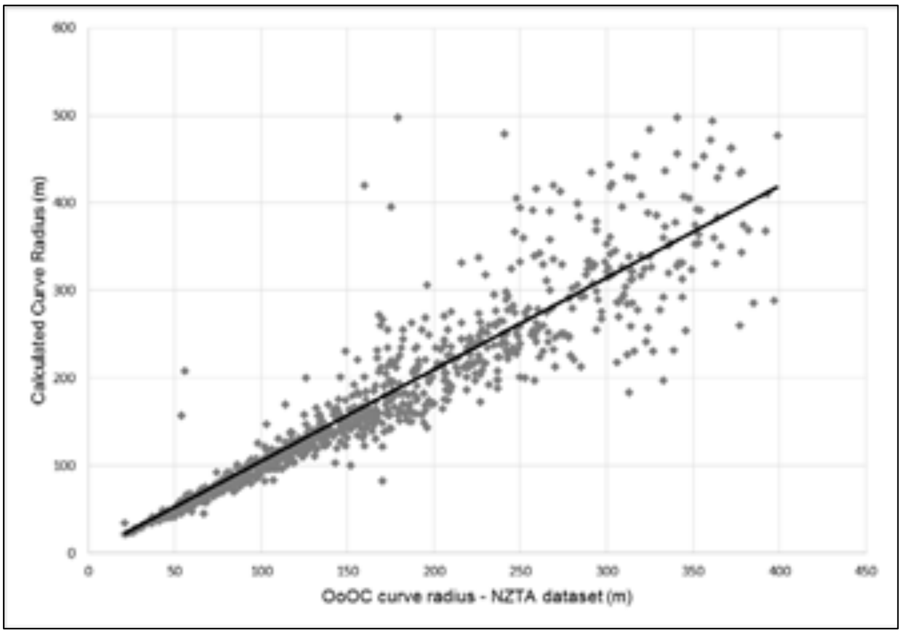


Figure 5: Comparison of calculated curve radii against NZTA out-of-context curve dataset

Calibration

Because the curve identification methodology developed for this project was new and untested, the results were compared against an existing New Zealand Transport Agency out-of-context curve dataset for the State Highway network in the Eastern Bay of Plenty region to assess the accuracy of the methodology.

The new methodology accurately identified the location of 96.8% of curves in the State Highway dataset, with a high correlation between curve radii values ($R^2 = 0.86$) (Figure 5).

The strong correlation between the automated operating speed model results and State Highway out-of-context dataset indicated that the new method developed for the signature project could be robustly applied to any road network regardless of the presence of comprehensive high-speed geometric data, including superelevation.

Results

The curve identification methodology recognised 6,985 curves across the EBoP region. Each curve was classified by design limit (in both directions) according to the Austroads operating speed model (Figure 4). The number of curves identified by category are displayed in Table 3. Where curves were classified differently in opposing directions, the worst (most out-of-context) classification has been applied. For example, a curve that is 'undesirable' in one direction but 'within limit' in the reverse direction would be categorised as 'undesirable'.

Table 3: Eastern Bay of Plenty curve categorisation

Curve Category	Total Curves	% of all Curves
Unacceptable	600	8.6%
Undesirable	815	11.7%
Desirable	941	13.5%
Within Limit	4629	66.3%

Correlation between curve category and loss-of-control crashes

Further analysis was undertaken to identify the number and percentage of loss-of-control crashes by curve category. For the purposes of this analysis, loss-of-control crashes were defined as those with movement code 'BF', 'DA' or 'DB' in CAS. In the 10-year period from 2004 – 2013, there were 589 loss-of-control crashes on the curves identified. The number and percentage of loss-of-control crashes by curve category are presented in Table 4.

Table 4: Eastern Bay of Plenty loss-of-control crashes by curve category

Curve Category	Total LOC Crashes	% of all LOC Crashes
Unacceptable	226	38.4%
Undesirable	166	28.2%
Desirable	64	10.9%
Within Limit	133	22.6%

The results show that two thirds (66.6%) of all loss-of-control crashes occur on out-of-context curves i.e. those identified as 'unacceptable or 'undesirable'. This is a particularly important finding as it means road controlling authorities in the Eastern Bay of Plenty region could target efforts on 20.3% of all curves where 66.6% of all loss-of-control crashes occur. The relationship between curve category and loss-of-control crashes is shown in Figure 6.

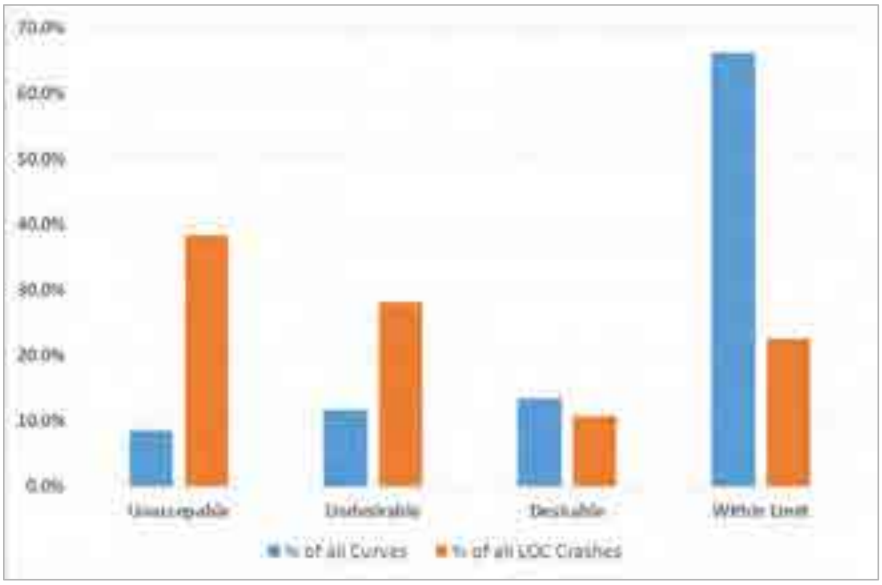


Figure 6: Curve category and loss-of-control crashes relationship

Further analysis of the number of loss-of-control crashes by curve category (Figure 7) demonstrates that curves rated 'unacceptable' or 'undesirable' in either direction have a higher incidence of loss-of-control crashes compared to curves that are within context ('desirable' or 'within limit'). This demonstrates that the relative risk of a rural curve is a function of the extent to which the curve is out-of-context with the approach speed.

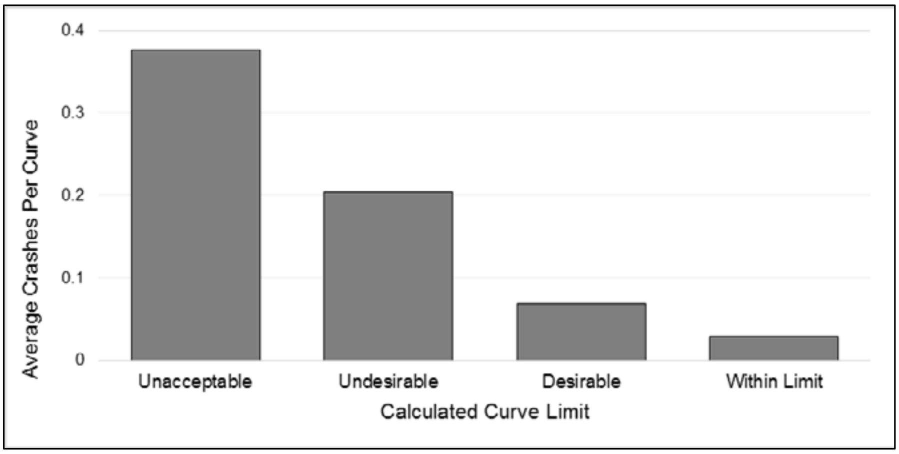


Figure 7: Loss-of-control crashes per curve by curve limit class

Output

The deliverable was a mapping website ("SignatureNET") displaying the risk metrics generated from the analysis, as well as contextual road safety data including administrative boundaries, communities at risk [7], crashes (categorised by crash severity and cause), and census statistics including deprivation and access to motor vehicles (Figure 8). The SignatureNET web viewer is available for all the signature project partners to access and query and features Google Streetview integration to allow users to view actual road conditions.

Figure 8: SignatureNET mapping website screenshot

Discussion and conclusion

SignatureNET and the new high risk curve assessment methodology demonstrate that innovative assessment methods and tools can be developed within a safe system signature project environment. Combining the speed and risk prediction models and related context data into a single mapping website has also provided the signature project partners with a tool to make well-informed road safety investment decisions. Both the SignatureNET website and underlying analysis can now be readily rolled-out across other regions using existing data and GIS methodologies.

The curve identification and analysis techniques presented in this paper will be of particular interest to road controlling authorities wanting to reduce loss-of-control crashes on rural roads. The output represents the first network screening tool that has been developed specifically to address the primary road safety risk in low volume rural areas in New Zealand – loss of control crashes on curves. As such, the model has the potential to benefit communities where road safety has been delivered in a largely reactive manner – which in low volume networks especially is usually a very ineffective way of deploying road safety funds.

The operating speed model provides a proactive approach of targeting to risk at a network-wide level. As a result, road controlling authorities can now make better informed decisions about the use of their limited road safety funds in a more efficient manner. The tool is sufficiently sophisticated that curves may be considered out-of-context in one direction of travel, but not the other, thereby enabling road controlling authorities to treat specific approaches rather than both directions. This then enables limited road safety budgets to reach a greater number of high-risk locations within the region.

There is a wide range of potential applications of the outputs, ranging from low cost interventions to enhance delineation on high-risk curves e.g. edge marker posts, curve warning signs and chevrons, through to informing the potential for reductions in fatal and serious trauma if speed limits are reduced.

Further enhancements to the speed model and high-risk curve identification include:

- Enhancing the speed model by exploring the relationship between curve risk category, road surface and carriageway widths and actual road safety performance.
- Exploring the relationship between curve risk category, star rating and the road safety performance of State Highways

- Enhancing the speed model by comparing calculated operating speeds against known operating speeds, for example using data collected using GPS.

Acknowledgements

The authors would like to acknowledge the New Zealand Transport Agency and the Accident Compensation Corporation (ACC) for supporting this project.

References

1. Austroads. Guide to Road Design Part 3: Geometric Design. Sydney, NSW, Australia: Austroads Incorporated, 2009.
2. Brodie, C., Durdin, P., Fleet, J., Minnema, R. & Tate, F. Urban KiwiRAP: Road Safety Assessment Programme. Paper presented at the Australasian College of Road Safety Conference, Adelaide, November 2013.
3. Cenek, P. D., Brodie, C. A., Davies, R. B. & Tate, F. A Prioritisation Scheme for the Safety Management of Curves. Paper presented at the 3rd International Road Surface Friction Conference, Gold Coast, Queensland, May 2011. http://www.nzta.govt.nz/resources/safety-management-of-curves/docs/safety-management-of-curves.pdf
4. Ministry of Transport (MoT). Safer Journeys New Zealand's Road Safety Strategy 2010-2020, Ministry of Transport, 2010.
5. New Zealand Transport Agency (NZTA). NZTA's Economic Evaluation Manual – Volume 1, 2010.http://www.nzta.govt.nz/resources/economic-evaluation-manual/volume-1/
6. New Zealand Transport Agency (NZTA). Safer Journeys Action Plan 2013-2015, New Zealand Transport Agency (NZTA) 2013. http://www.saferjourneys.govt.nz/assets/Uploads/Safer-Journeys-Action-plan-2013-2015.pdf
7. New Zealand Transport Agency (NZTA). Communities at Risk Register, April 2014. http://nzta.govt.nz/resources/communities-at-risk-register/docs/register-2014.pdf
8. New Zealand Transport Agency. (2014a). Crash analysis system [dataset], New Zealand Transport Agency (NZTA), 2014. Retrieved from http://www.nzta.govt.nz/resources/crash-analysis-system-data/index.html
9. University of Otago – National School of Surveying. NZSoSDEM V1.0 (Digital Elevation, 2011 Model). http://www.otago.ac.nz/surveying/research/geospatial/otago040574.html#nzsosdem

Conference Gala Dinner & Award Ceremony

Thursday 15 October 2015

Gold Coast – Australia

A Celebration of Excellence in Road Safety!

ARSC2015 will include the Australasian College of Road Safety Awards, recognising and celebrating exemplary projects and people working so hard across our region to save lives and reduce injuries on our roads.

This prestigious award ceremony will take place at the inaugural 2015 Australasian Road Safety Conference, which is the result of a successful merger of Australasia's two premier road safety conferences: the Australasian College of Road Safety Conference, and the Australasian Road Safety Research, Policing and Education Conference.

The 2015 Australasian College of Road Safety Awards will continue the tradition of the original Australasian road safety awards and conferences by recognising and celebrating exemplary projects and people working hard across our region to save lives and reduce injuries on our roads.

These awards will include the following presentations:

- The prestigious Australasian College of Road Safety Fellowship Award in recognition of exemplary contribution being made by an individual to road safety in Australasia. This award has been recognising outstanding individuals since its inception in 1991. In 2014 the ACRS Patron, the Governor-General of Australia Sir Peter Cosgrove presented this award.
- Australasia's premier road safety award recognising projects that exhibit exemplary innovation and effectiveness to save lives and injuries on roads – the 3M-ACRS Diamond Road Safety Awards. This award is entering its 5th year and is recognised as Australasia's premier road safety award recognising an outstanding road trauma reduction project. In 2014 the ACRS Patron, the Governor-General of Australia Sir Peter Cosgrove presented this award.
- ARSC2015 Conference Awards (presented in the closing session of the conference).
- Other awards as deemed appropriate by the joint hosts for 2015: ACRS, Austroads and CARRS-Q.

We look forward to bringing you more information about the awards shortly. Most importantly we encourage your participation at this important event, which recognises our outstanding individuals, organisations and projects as we all strive to reduce road trauma.

Austroads, CARRS-Q and the ACRS look forward to your participation in this important event which aligns with international, Australasian and national road safety efforts, and is a significant step forward in Australasia's road safety strategy.

More information is available at:
http://theaustralasianroadsafetyconference.com.au

To join the mailing list contact:
eo@acrs.org.au

Award Entries Open
1 May 2015 and close 5pm EST 1 August 2015

Autonomous Emergency Braking.

In order to avoid, or minimise the impact of, a crash, **Autonomous Emergency Braking (AEB)** systems use sensors to detect obstructions in a vehicle's path and automatically apply the brakes if the driver does not respond.

Ask for AEB when you buy your next 5 star car.

ANCAP Safety ★★★★★

Accept nothing less.

ancap.com.au

Protect the Riders...
Pad the Posts

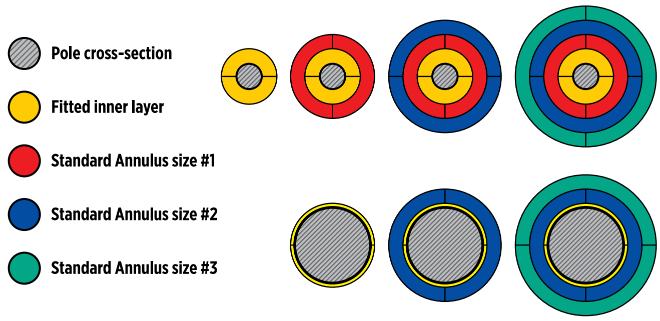
Developed by road safety systems and engineering specialists LB Australia Pty Ltd *ImpactProtect* reduces the risk of serious injuries to motorcyclists and cyclists during an impact with a roadside post or pole.

Suitable for use on posts and poles of all shapes and sizes, and in a full range of installation locations – from suburban streets, bike paths and recreation trails, through to rural roads, highways and freeways - ImpactProtect incorporates a fitted inner layer followed by a series of standard sized protectors (fitted annuli) each of standard thickness, composition and head impact criteria (HIC) performance at a given speed. The greater the number of layers fitted, the higher the level of protection.

For the road safety industry this a unique, bespoke solution offering the engineer options, with layers of protection to ensure a level of safety appropriate for the site.

Modular Impact Protection

The *ImpactProtect* system is available as a single or multi-layer solution to suit post and poles of all shapes and sizes, and in all manner of installation location. The modular nature of the system allows for a choice of impact protection level to suit to specific application or location. Put simply, the more layers used, the greater the level of impact protection



IMPACT PROTECT

For further information on the *ImpactProtect* impact attenuator system, contact LB Australia Pty Ltd, Ph: (02) 9631 8833 or Email: roadsafety@lbaustralia.com.au

Australasian College of Road Safety Inc.

ACRS, PO Box 198, Mawson ACT 2607 Australia
Tel 02 6290 2509
Fax 02 6290 0914
Email eo@acrs.org.au
Head Office
Pearce Centre, Collett Place, Pearce ACT Australia

Visit the College website at www.acrs.org.au

Proudly sponsored by
LB Australia
New South Wales Government
and ANCAP