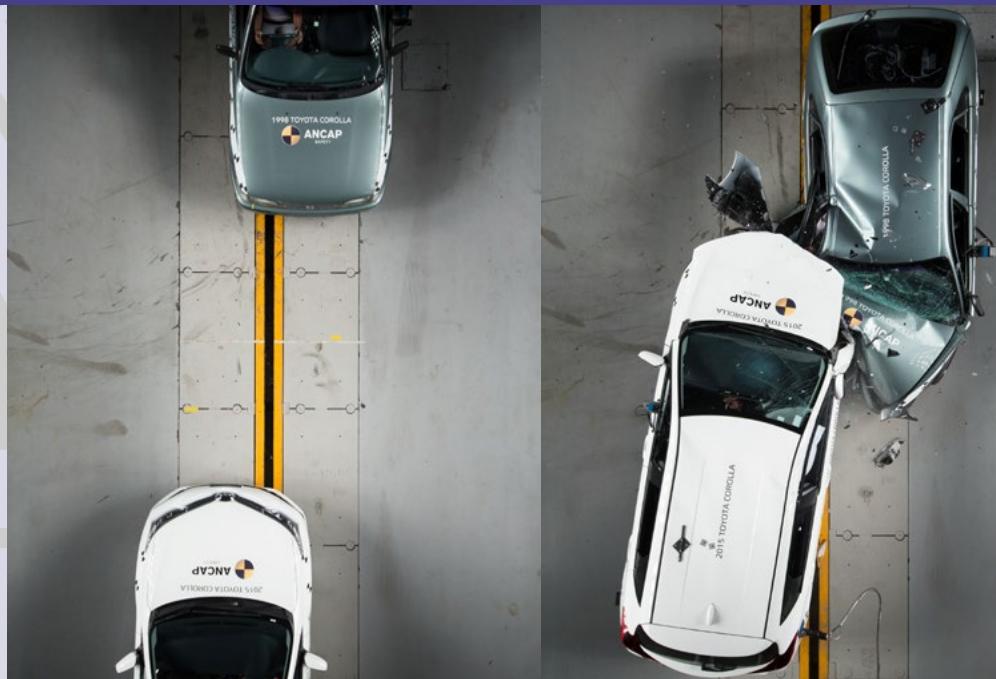




Journal of the Australasian College of Road Safety

Formerly RoadWise – Australia's First Road Safety Journal



RAD SAF

Peer-reviewed papers

Original Road Safety Research

- Recording of alcohol in official crash statistics: underreporting and procedures to improve statistics
- Analysis of trends in the composition of Australasian vehicle fleets associated with pedestrian injury severity
- A Systematic Review of Bicycle Helmet Laws Enacted Worldwide
- Safe Roads for Cyclists: An Investigation of Australian and Dutch Approaches
- Development of a pedestrian injury prediction model for potential use in an Advanced Automated Crash Notification (AACN) system

Contributed articles

Road Safety Policy & Practice

- The Age of Light Vehicles Involved in Road Fatalities

Perspective on Road Safety

- Safe Speeds Part 1: Political Decisions and the Limited Adoption of Speed Management for Road Safety

Interested in road safety crash data?

Interactive crash statistics available for NSW

To better understand road safety issues and trends, Centre for Road Safety road crash data is available via interactive reports.

Dynamic reports include detailed NSW statistics on road user deaths and serious injuries, crash types, injury trends and locations. Presentations and road safety data reports on speed, drug driving, heavy vehicles and younger drivers are also available on the website.

Serious injuries 2017p

Road user:

1110

WALKING



829

1967

ON BICYCLES



1200

5846

IN VEHICLES



3335
2351

2551

MOTORBIKES



1335
1142

Gender:

7760

MALES



4433



3122

4295

FEMALES



2585
1607

Sydney RMS Region Rest of NSW

P = Preliminary and subject to change.

Excludes unknown locations, road user and gender. RMS Region is a proxy for Roads and Maritime Services (RMS) Region derived from the location of the hospital where the person was first admitted.

Visit roadsafety.transport.nsw.gov.au/statistics to view the latest Quarterly Bulletin of Serious Injury Crash Data and interactive crash statistics.



Lives lost on NSW roads.
Our goal is zero.





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International Convention Centre Sydney
3–5 October 2018

FOUNDING PARTNERS



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The Australasian College of Road Safety (ACRS) and Austroads invite you to attend the largest road safety-dedicated conference in the Southern Hemisphere. The 2018 Australasian Road Safety Conference (ARSC2018) will be held in Sydney at the International Convention Centre from Wednesday 3 to Friday 5 October 2018.

ARSC2018 will showcase the region's outstanding researchers, practitioners, policy-makers and industry spanning the plethora of 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. ARSC2018 will bring with it a special focus on engaging all levels of government and community, from the city to the bush, to move "Towards Zero – Making it Happen!" The comprehensive 3-day scientific program will showcase the latest research; education and policing programs; policies and management strategies; and technological developments in the field, together with national and international keynote speakers, oral and poster presentations, workshops and interactive symposia.

WHO SHOULD ATTEND?

With a record number of submissions received, ARSC2018 is expected to attract over 700 delegates including researchers, policing and enforcement agencies, practitioners, policymakers, industry representatives, educators, 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, and vehicle safety.

To register your expression of interest as a delegate, speaker, sponsor or trade exhibitor, or for further information about the Conference, please visit www.australasianroadsafetyconference.com.au. Additional enquiries should be directed to the Conference Secretariat, Encanta Event Management on +61 3 9863 7608 or ARSC@encanta.com.au.

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NOW OPEN**



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Situated on a breathtaking harbour, Sydney is one of the world's most attractive and exciting cities. With its rich mix of colonial and indigenous history, multicultural cuisines and festivals, museums, exhibitions and theatres, Sydney is an experience waiting to happen. Enjoy the mild sunny climate and miles of golden beaches. Stroll along Darling Harbour, The Rocks and Circular Quay enjoying the sights of the world famous Opera House, or climb the Sydney Harbour Bridge. The new ICC Sydney is Australia's first fully-integrated convention, events, exhibition and entertainment centre, and is located at the heart of its very own Sydney harbour waterfront precinct, set amongst restaurants, retail and a vibrant public domain on Darling Harbour.

www.australasianroadsafetyconference.com.au



**ACRS Awards - held at the Gala Dinner
during the ARSC2018 Conference**
3-5 October
Sydney International Convention Centre

**Doltone House,
Jones Bay Wharf,
Sydney Harbour
Thursday 4 October 2018**

The Australasian College of Road Safety Awards 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 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.
- 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 Award**. This award is entering its 8th year and is recognised as Australasia's premier road safety award recognising an outstanding road trauma reduction project.
- ARSC Conference Awards (presented in the closing session of the Australasian Road Safety Conference)
- Other awards as deemed appropriate by the joint hosts for the ARSC Conference: **ACRS, Austroads** and invited hosts for each year.

Austroads, ARRB, TARS @UNSW and the ACRS look forward to your participation in ARSC2018 which aligns with international, Australasian and national road safety efforts, and is a significant step forward in Australasia's road safety strategy. 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.

More information is available at:
www.theaustralasianroadsafetyawards.com.au

***Presentation of a trip to USA
for exemplary road safety efforts!***

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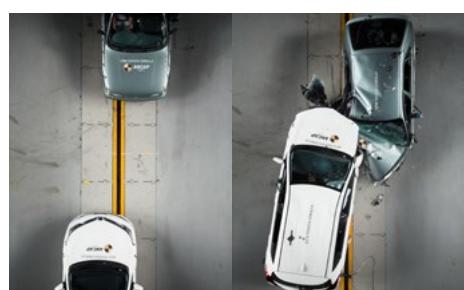
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Cover image

Australasian New Car Assessment Program's (ANCAP) car to car crash test between two Toyota Corollas, but of significantly different ages, demonstrate the differences in occupant safety levels between older (silver car) and newer (white car) vehicles. See *Road Safety Policy & Practice* article (Smith (2018). The Age of Light Vehicles Involved in Road Fatalities. *Journal of the Australasian College of Road Safety*, 29(3), 58-64) showing older vehicles over-represented in occupant fatalities between 2012 and 2016 in Australia and New Zealand.

Disclaimer

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The Journal of the Australasian College of Road Safety
(formerly **RoadWise** between 1988 and 2004) ISSN 1832-9497.
Published quarterly by the *Australasian College of Road Safety*.

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Editorial Policy

The *Journal of the Australasian College of Road Safety* aims to publish high quality papers and provides a means of communication for the considerable amount of evidence being built for the delivery of road safety, to inform researchers, policymakers, advocates, government and non-government organisations, post-crash carers, engineers, economists, educators, psychologists/behavioural scientists, communication experts, insurance agencies, private companies, funding agencies, and interested members of the public. The Journal accepts papers from any country or region and has an international readership.

All papers submitted for publication undergo a peer-review process, unless the paper is submitted as a *Perspective/Commentary on Road Safety* or *Correspondence* or the authors specifically request the paper not to be peer-reviewed at the time of original submission. Submissions under the peer-review stream are refereed on the basis of quality and importance for advancing road safety, and decisions on the publication of the paper are based on the value of the contribution the paper makes in road safety. Papers that pass the initial screening process by the Managing Editor and Peer-Review Editor will be sent out to peer reviewers selected on the basis of expertise and prior work in the area. The names of the reviewers are not disclosed to the authors. Based on the recommendations from the reviewers, authors are informed of the decision on the suitability of the manuscript for publication.

When papers are submitted and the authors specifically request the paper not to be peer-reviewed at the time of original submission, the papers will be published under the non peer-review stream. Submissions under the non peer-review stream, *Perspective/Commentary on Road Safety* and *Correspondence* are reviewed initially by the Managing Editor, who makes a decision, in consultation with the Peer-Review Editor and/or Editorial Board when needed, to accept or reject a manuscript, or to request revisions from the author/s in response to the comments from the editor/s.

As a rule of thumb, all manuscripts can undergo only one major revision. Any editorial decisions regarding manuscript acceptance by the Managing Editor and Peer-Review Editor are final and further discussions or communications will not be entered into in the case of a submission being rejected.

For all articles which make claims that refute established scientific facts and/or established research findings, the paper will have to undergo peer-review. The Editor will notify the author if peer-review is required and at the same time the author will be given the opportunity to either withdraw the submission or proceed with peer-review. The Journal is not in the business of preventing the advancement or refinement of our current knowledge in regards to road safety. A paper that provides scientific evidence that refutes prevailing knowledge is of course acceptable. This provision is to protect the Journal from publishing papers that present opinions or claims without substantive evidence.

All article types must be submitted online via the Editorial Manager: <http://www.editorialmanager.com/jacrs/default.aspx>. Online submission instructions can be downloaded from: <http://acrs.org.au/contact-us/em-journal-conference-contacts/>.

Important information for authors

It is essential that authors writing for the Journal obtain and follow the **Instructions for authors**. These are updated regularly and can be downloaded from the College website at <http://acrs.org.au/contact-us/em-journal-conference-contacts/>

Authors are responsible for complying with all the requirements (including Article types, Article structure, References, Ethics in publishing, Originality & plagiarism, Author declaration) before submitting their papers. The College has adopted guidelines developed by the Committee on Publication Ethics, which are available at <http://acrs.org.au/publications/journals/ethics-and-malpractice-statement/>.

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From the President



In the last Journal I encouraged readers to look over the “silo” of their expertise and help contribute to the bigger picture of the many factors we need to improve to reduce road trauma. Sometimes the solutions to problems we face are self-evident to others who have different experiences and data. Building modern cross issue communication networks are vital.

Roads are multi-purpose infrastructure. The users include pedestrians, cyclists (pedal and electric), two-wheelers, drivers of cars (small to large, old and new), trucks and buses of all sizes, and perhaps some others that we prefer did not use the roads due to lack of safety. These users directly or indirectly compete to be beneficiaries of those roads, just as property owners try to maximise their benefits along the roads for domestic, industrial, retail or service purposes.

The risks in using the road vary for every user, risks which are often not well understood by users. These risks vary with many factors; country; region; culture; traffic; vehicle age, type and capacity; road capacity and quality; management, regulation and enforcement; trauma care; to name some examples. We classify

the users into vulnerable and non-vulnerable groups, and make comparisons across different user groups as well as across other factors. Papers in this Journal address some of the complexities we face in understanding the risks, the classifications and the comparisons; emphasising the importance of the detailed work needed in “silos” and perhaps the work needed to build the new communication networks needed to ensure we can benefit from the work of others.

Road safety professional skills, capacity, expertise are factors we need to build, extend and improve if we are to be effective “Towards Zero”.

I remind readers to register for the Australasian Road Safety Conference in Sydney in October (<http://australasianroadsafetyconference.com.au>). That Conference is an important opportunity for all delegates to improve skills and capacity; to maintain, open and build communication networks; to build bridges between silos; to learn of and question new ideas, new research, new developments, new technologies, successful projects; and to hear from leaders in academia, government, industry and the professions on a very wide canvas of road safety issues. You will be very welcome.

*Lauchlan McIntosh AM FACRS FAICD
ACRS President*

ACRS Chapter reports

Chapter reports were sought from all Chapter Representatives. We greatly appreciate the reports we received from ACT and Queensland.

Australian Capital Territory (ACT) and Region

The ACT and Region Chapter held its Annual General Meeting on 2 May 2018. The Meeting re-elected unopposed the current office holders for the 2018-19 year:

Eric Chalmers: Chair and National Executive Representative;
Keith Wheatley: Secretary; and
Steve Lake: Treasurer.

It also ratified the work program proposed by the Chapter committee in February 2018 which was outlined in the previous Journal report:

- **Graduated Licensing Forum** The Forum, to be held on behalf of the ACT Government, and will provide an opportunity for key stakeholders to assess the responses from recently completed public consultations with the ACT community on future options for strengthening the Territory's Graduated Licensing System. The Forum will be undertaken upon completion of the analysis of consultation feedback task.
- **Sharing the roads with vulnerable road users on rural roads in ACT and surrounding NSW** This project will bring together a range of organisations in all areas of the region to consider safety issues associated with the interaction of vulnerable road users and heavy vehicle commercial traffic on rural roads in the ACT and region.
- **Wild life crashes in ACT and surrounding area** Discussions have commenced between the Chapter, ACT Health and the Royal Australasian College of Surgeons on the availability of data on the extent of crashes and their severity in the region following concerning trends in trauma cases. Nearby NSW local government councils will participate. Discussions are also being held with motor insurers to see if they can assist in providing information that will result in a more comprehensive data base.
- **Automated Vehicles - Benefits and challenges** This activity will have a wide appeal to the general public. It will provide a broad realistic introduction to the use of automated vehicles in Australia. Initial planning will commence towards the end of 2018.

The Chapter will continue to strengthen its relationships with organisations with an integral interest in and ability to influence the improvement of safety outcomes in the ACT and extended areas in the region where traffic and transport operations interact.

*ACT Chapter Chair and Secretary
Mr Eric Chalmers & Mr Keith Wheatley*

Queensland (QLD)

Safe System Workshop: Demolishing the Silos, 5 June 2018

On Tuesday 5th June, the Queensland Chapter of the Australasian College of Road Safety conducted a workshop on the Safe System approach, with the title "Demolishing the Silos". The Queensland Department of Transport supported the workshop through provision of the conference facilities in their Mary Street offices, and CARRS-Q provided organisational assistance. The workshop was attended in person by about 80 participants, and approximately 60 people followed a live stream of the workshop from various locations around Brisbane, plus Beachmere, Buderim and Maroochydore in Queensland, and Melbourne and Adelaide.

The workshop was organised in two sections. After an Introduction by Chapter Chair Mark King, Barry Watson gave an overview of the background to the Safe System approach and its important characteristics; this was followed by presentations from three invited speakers who highlighted cases of successful implementation of a Safe System approach at State level (Bruce Corben, of Victoria, on speed management interventions), regional level (Colin Edmonston, of TMR, on cross-sectoral and cross-profession implementation experiences in Central Region) and community level (Peter Frazer, President of SARAH, on the Safe System and community advocacy).

After a break, a panel session was held involving our invited speakers Bruce Corben, Colin Edmonston and Peter Frazer, plus Dennis Walsh of Transport and Main Roads and Assistant Commissioner Mike Keating of the Queensland Police Service Road Policing Command. The session was chaired by Barry Watson and was focused on each panellist's views on how they apply the Safe System approach in their work and the challenges involved. After a brief Q&A session, Mark King closed the Workshop, flagging that it is the first step in a longer process of working through the implications of the Safe System approach for practitioners.

Annual General Meeting, 5 June 2018

The Safe System Workshop was followed by the Annual General Meeting, which was well attended. The following office bearers were elected:

Chair: Mark King
Deputy Chair: Simon Kirkpatrick
Secretary /Treasurer: Veronica Baldwin
Committee: Narelle Haworth, Joel Tucker,
Vanessa Cattermole, Matthew Waugh,
Ioni Lewis, Kerry Armstrong

Next meeting, 5 September 2018

The seminar at the next meeting will be on the National Road Safety Strategy, and will be presented by Austroads Road Safety Manager David Bobbrenen. The venue will be room K424 in K Block at QUT Kelvin Grove, the building where CARRS-Q is located (130 Victoria Park Rd, Kelvin Grove).

QLD Chapter Chair
Dr Mark King

ACRS News

A FEW MONTHS TO GO UNTIL THE ARSC2018 AT SYDNEY'S ICC, DARLING HARBOUR!

The Conference Program promises to provide delegates with the latest on road safety research and practice from across Australia and New Zealand with **presentations** across themes including:

- Fitness to drive/licensing
- Road Safety Communication
- Policing: Traffic offenders
- Rural Road Safety
- Motorcycle safety
- Drug and alcohol impaired driving
- Policing: seat belt, pursuits, alcohol interventions
- Road Safety in LMICs
- Novice Drivers: Training Programs
- Driver behaviour: new insights into fatigue and distraction
- Older drivers
- Cyclist safety: new research
- Infrastructure
- Emergency response and rehabilitation
- Crash analysis
- Vehicles in the workplace
- Cycling: education and behaviour
- ITS & AD Estimated benefits and trials
- Driver behaviour and road infrastructure
- Speed management in different settings
- Crash analysis: cyclists

- Road Safety in work settings
- ITS & AD Behaviour & Acceptance
- Heavy Vehicles
- Roadside Treatments
- Policy: Novice driver safety
- Transport planning for mobility and safety
- Road safety in and around schools
- Inclusiveness and driving
- Pedestrian safety
- Driver Distraction
- Policy: Setting goals for the future
- Child restraints

Global perspectives on road safety will be provided by prominent Keynote and Plenary session speakers from across the globe, engaging with some of Australasia's leading road safety researchers and practitioners, discussing contemporary issues relevant to local and state government practitioners, road safety researchers, people whose workplace are vehicle-based, workplace health and safety and fleet managers etc. with plenary session topics including:

- Where Does Road Safety Strategy/Planning and Action Need to Go?
- Road Safety in the Context of the Vehicle as a Workplace
- Integrating Road Safety into Road Transport Planning

The Conference will include dedicated Workshops with particular focus on the following sectors:

- Road Safety Education - Workshop
- Road Safety Policing- Workshop
- Local Government response to road safety- Workshop

The Conference will include around 200 concurrent session presentations and 14 symposia sessions with speakers expanding on topics which will be highly engaging for Conference delegates. Each symposium is a dedicated 90-minute session focussing on a particular theme. The successful Symposia from a very competitive field of submissions include the following:

1. Motorcycle Awareness Week
2. Low- and Middle-Income Countries
3. Emerging Methods
4. Debate: Safe Systems – Where do we go?
5. Getting the Inside Scoop
6. Post-Crash Response
7. The Workplace, why does Road Safety Management Vary so much?
8. Advanced Vehicle Technologies and Automation
9. Reducing Fatigue-Related Crashes
10. Cyclists, Heavy Vehicles and Safety
11. Data linkage
12. Safe System Road Infrastructure Program (SSRIP)
13. Construction Logistics and Community Safety
14. Current and Emerging Challenges and Opportunities in Level Crossings

For further information, please visit
<http://australasianroadsafetyconference.com.au/>
for the Conference and
<http://theaustralasianroadsafetyawards.com.au/>
for the Awards.

ACRS ANNUAL GENERAL MEETING OUTCOME: PRESIDENT'S 2018 AGM REPORT

I am privileged to be able to deliver my Annual Report on behalf of the Executive Committee at this 2018 AGM. Our activities continue to grow.

We continued to have the patronage of our Governor General, General Sir Peter Cosgrove, AK, MC, and throughout the year support from the Hon Darren Chester MP and also the Parliamentary Friends of Road Safety, co-chaired by Senator Alex Gallacher and Llew O'Brien MP as well as other parliamentarians across Australia.

However, while in 2017 road deaths in Australia decreased by 68 to 1225 compared with 2016 total of 1293 our five year average number of deaths is up by 1.8%. In New Zealand, in 2017, 379 people died in road crashes, up by 52 on the previous year.

Last year in my report I quoted Professor Narelle Haworth's call to "stop counting the dead and start counting the injured if road safety is to be improved..." Injury reporting is improving with new projects, but in Australia alone we are

still unsure of the real numbers of serious injuries from road crashes, which could be over 40,000 pa and increasing.

Our task at the College, as set out in our Constitution, is to foster closer communication, to be a focus, to encourage, to be forum, to promote best practice on road safety programs and initiatives, to work for the reduction of the road toll then, is a vital one.

The Australian Government in mid 2017 announced a new inquiry into the National Road Safety Strategy. I said at last year's AGM we needed action on agreed solutions, not more inquiries. I have to report that despite my call for real action, the Inquiry is underway and led by two College members, Associate Professor Jeremy Woolley and Dr John Crozier with another two members, Rob McInerney and I as Advisors. This Inquiry has consulted widely and will report to the responsible Australian Minister, the Hon Michael McCormack, shortly. Advocating support for the actions to be recommended will be a key role for the College this year.

While I am concerned at the potential an Inquiry process may have in delaying new actions, I do not to diminish the large body of work that is being done by College members and others in many fields, to reduce road trauma. We should always remember that while we may be disappointed that the trauma reduction targets are not being met, our rates are lowering and many are alive and uninjured as a result of successful programs and actions by people in governments, universities, industries, associations, communities and companies. I extend my sincere thanks to everyone involved across Australia and New Zealand.

I also specifically thank our Vice Presidents, David Healy and Eric Chalmers, the Executive Committee, and the many College Chapter Chairs and officers for their local seminars and networking events. David Healey is retiring this year as a Vice President but will still remain an active member of the Melbourne Chapter. I acknowledge and thank David for his support over many years, he has been a stalwart for the national as well as local activities of the College.

We recognised the long term personal contribution across so many areas of road safety for the last 24 years by Samantha Cockfield and were delighted to honour her this year with a College Fellowship. Eric Chalmers was the worthy winner of the 3M-ACRS Diamond Road Safety Award for the ACT Kidsafe program "Zero Deaths and Injuries for Children under 7".

Finalists for this award came from many areas. These included new ideas and actions from local and state government groups, collaborative programs led by local and regional police groups, individuals passionately pursuing specific projects to reduce risk, industry associations and transport companies implementing programs with targets to ensure safe operations, news programs, and specific education for specialist groups. We were also pleased to have many specific award winners at the Australasian Road Safety Conference in Perth.

Growth of the College itself comes from the contribution

from many, but in particular from Claire Howe, our CEO and her Office Manager Kim Winks. I thank them for their work in co-ordinating and communicating to you on a wide range of road safety issues, responding to requests, as well as managing the activities necessary to keep the College developing and running so well. Claire's weekly E-Alert provides a valuable weekly snapshot of road safety activities to members and is widely read by many others.

My thanks also are to our Past President, Raphael Grzebieta, also Managing Editor of the Journal and Journal Editor Dr Chika Sakashita, for their development of a new Editorial Board for the Journal, which itself continues to grow and provides an excellent vehicle for researchers and others to publish their work. Dr Sakashita has also become our representative at the UN Global Road Safety Collaboration. Support from many sponsors for the Journal, Awards and the Conference is greatly appreciated.

For the College in December 2017 we were honoured with the receipt of a Prince Michael International Road Safety Award in the Road Safety Management category for Road Safety Advocacy. Our citation noted the College "provided a rich collaborative environment promoting communication, networking professionalism and advocacy across all spheres of road safety including policy, advocacy, research, application and dissemination." Attendance at the Award Ceremony in London gave the College an opportunity to participate in the Global Legislators for Road Safety Forum at the House of Commons, a Forum which has the potential to assist in educating and empowering politicians across the globe and specifically in Australasia to be advocates for the introduction of safe system road safety principles.

You will note from the Financial Report that we have begun to move to a more sustainable position with an improvement in reserves and we are planning for a small surplus in the Budget recommended for your approval this year. The Budget is for modest expenditure increases in our administration to meet our growth, and in particular an allocation of funds for specific projects (subject to specific Executive Committee approval) to update our website and an organisation review.

This sustainable position is due to the continued success of our administration and also of the management of the Australasian Road Safety Conference over the past three years. In conjunction with our partners Austroads, many sponsors, staff and the voluntary efforts of members, we have been able to build and host an annual Conference for some 700 delegates and exhibitors from across Australasia and the Region.

The outreach of the Conference with sponsored scholarships from rural and remote, as well as low and middle income country area delegates was very successful. The Conference is continuing to expand, providing an excellent opportunity for the vital networks needed to enhance the knowledge and skills needed to reduce road trauma. The Conference in Sydney this year I am sure will meet this growing demand. However, we need to recognise the importance of ensuring we continue to be viable.

We have sought financial support for increasing our activities again from the Federal Government in Australia, although we have unfortunately not yet had any specific response. Neither have we had a response to our detailed submission to all Federal Parliamentarians which outlined Australia's stalled progress against National Road Safety Strategy 2011-2020 targets for death and injury reduction, the multi-portfolio impacts of road trauma across the spectrum of federal departments, and presented comprehensive recommendations on the way forward to reduce road trauma. While we have been in regular contact with the relevant Federal Department and responsible Ministers, many parliamentarians and their staff throughout the year who do offer support, there is more for us to do.

As we grow and expand it is timely to review our own strategy and to update our policies and procedures. I have encouraged the Executive Committee recently to consider in this age of "disruption" how we can meet our objectives and how relevant we can be to ensure we can meet the tasks set out in our Constitution.

There are motions before the members at the AGM to authorise such a review which may require some changes to the Constitution, to also add a new policy to ensure we operate at best practice in dealing with each other and the community, and I commend those motions to you.

I would expect this review, if approved, and led by the incoming Executive Committee, may be able to report at around or just after the Conference with a view recommending any new structures or processes for member approval, if needed, either at the AGM next year or before at a Special Meeting. Such a review would recommend Governance and Administration roles and policies for the future.

The College is extending its reach as we have agreed to do, and I believe is continuing to improve the building of the road safety knowledge base, enhancing collaboration and advocating in many areas for programs and actions to reduce so much unnecessary road trauma.

I reiterate my appreciation for the support from the membership, the staff and the sponsors, together we can continue to make a contribution to the vital task to save lives and injuries, working towards the goal of zero deaths and a major reduction in injuries in our use of the roads.

Lauchlan McIntosh AM FACRS FAICD
ACRS President
 8 May 2018

ACRS ANNUAL GENERAL MEETING OUTCOME: CEO'S 2018 AGM REPORT

The last 12 months have been very productive for the College, and as CEO I am very happy to report that the Canberra office has managed to support such significant growth in the College over the last several years on such a minimal budget and limited staffing resources.

I'd like to thank our volunteer Executive Committee and office bearers both at Australasian and Chapter level who we heavily rely on, and am especially pleased that the growth of the College is supporting a justified lift in profile for our organisation, office bearers and indeed all members. This in turn helps maintain pressure on keeping road trauma levels and road safety improvements as a priority across the political and community spectrum. This flows to all other areas including supporting our researchers, policing and education agencies, and the many many other stakeholder groups who work so hard in this sector.

Much of the role of the Canberra office is centred on ensuring our members receive their benefit of membership to the College as well as supporting the wider group of stakeholders gain traction in terms of advocacy. In terms of member benefits, head office activities have included the following highlights:

- **PATRON:** Maintaining a positive relationship with our Patron, His Excellency Sir Peter Cosgrove, the Governor-General of Australia. We are hoping His Excellency will be able to join us all at ARSC2018 to help us celebrate the 30th Anniversary of the College – a huge milestone at such a prestigious event.
- **STAKEHOLDER ENGAGEMENT:** We continue to build on a positive working relationship with all stakeholders, including the now Deputy Prime Minister, Michael McCormack, also Minister for Infrastructure and Transport. Many of you will remember Michael from our ARSC2015 Conference Dinner where he spoke passionately about road safety and awarded the Fellowship to Rob McInerney and the 3M-ACRS Award to David Bobbermen and his team. Lauchlan and I met with the DPM shortly after he was elected to the position, and he reiterated his commitment to road safety and undertook to join us at ARSC2018 in Sydney. We also maintain a close relationship with the prior Minister, Hon Darren Chester who joined us in Perth for ARSC2017. We look forward to continuing this productive relationship to ensure our joint efforts have the best outcomes for road trauma reductions across our region and beyond.
- We also continue to be actively engaged with the Parliamentary Friends of Road Safety, particularly the co-Chairs Alex Gallacher and Llew O'brien, meeting independently and also arranging meetings with sector representatives.
- **CONFERENCES:** Due to the size and complexity of this event, the conference has become our major activity and where our somewhat limited resources are directed. At any time we will have 3 conferences active – for example at present we have ARSC2018 very much taking up our time, but we are also progressing ARSC2019 (we have locked in a venue, dates, signed contracts with various suppliers and have met with potential Platinum Sponsors) and ARSC2020 locations and venues are being considered and meetings being held. We are carefully managing staffing and finance around the conference as it has a major impact on the College's viability. We are very mindful and grateful for our ongoing very good relationship with Austroads, representing all levels of government for Federal, State and Local agencies. We have built a mutually respectful relationship which is underpinning the success of our conferences. For 2017, and again in tandem with Austroads, we held the third Australasian Road Safety Conference in Perth, an event which has now been cemented as the premier road safety-dedicated event in our region. Again a great deal thanks goes to Austroads (particularly Nick Koukoulas and David Bobbermen) and all Australasian road transport and traffic agencies for their continuing engagement and support in the merging of our two conferences.
- I am very pleased to report that in the last couple of days the federal Department has verbally confirmed support of \$50,000 for ARSC2018 LMIC Scholarships & Gold level sponsorship (a \$20,000 increase on prior support), and the ACT Government have again confirmed their commitment to sponsor our Early Career Professionals event for \$10,000.
- Thanks to this ongoing support from Austroads and our Executive Committee, Chapters and Fellows, and the support of around 650 delegates and more than 40 sponsors, exhibitors and supporters, Australasia's third Australasian Road Safety Conference (ARSC2017) was a great success. There were over 200 papers and posters, 13 workshops & symposia, plus keynotes, invited speakers & panellists who ensured there was something for everyone in our combined efforts to drive down road deaths and injuries. I would particularly like to thank Peter Frazer from the Safer Australian Roads and Highways Organisation for his continuing dedication and drive in this regard. In terms of ARSC2017, my sincere thanks go to Dr Paul Roberts and Professor Lynn Meuleners, our conference co-Chairs, the entire ACRS WA Chapter Executive Committee and members, and all of you for your generous support in ensuring the success of ARSC2017. We certainly could not continue to do this without your support.
- We are continuing the momentum with ARSC2018 to be held in Sydney in October this year, planning of which is well underway - thanks very much to Teresa Senserrick, David McTiernan, Lisa Keay, Julie Brown, Raph Grzebieta, Liz de Rome and the entire NSW Chapter for helping this along. We are

- joined again by our Founding Partner Austroads, plus ARRB and Transport for NSW, as Inviting Partners for ARSC2018. We thank the NSW Chapter for their generosity and continued hard work in ensuring the event is a success. The NSW Government have come on board to provide a generous \$100,000 Platinum Sponsorship.
- **AWARDS:** The College was thrilled to receive a 2017 Prince Michael Award for excellence in Road Safety Management, and I was very proud to help represent the College together with Lauchlan McIntosh, Chika Sakashita, Narelle Haworth, Soames Job, Rob McInerney, Jessica Truong, Iain Cameron, Llew O'brien MP and Senator Alex Gallacher. We were also thrilled that the Australian Deputy High Commissioner to London joined us to celebrate this milestone.
- During the past 12 months we have continued to celebrate outstanding achievements in the road safety sector at the 2017 ACRS Award Ceremony held during the ARSC2017 Conference Dinner, celebrating and rewarding the achievements of the many varied sectors working to reduce road trauma. The Canberra office continues to be the administrative hub for all of our awards and we work hard to promote and encourage wide-ranging applications to ensure best outcomes. For the 3M award we have built a very strong relationship with key 3M people and look forward to them having a higher profile at this year's conference as they are based in Sydney. A special congratulations to Sam Cockfield, our new ACRS Fellow, awarded for her outstanding commitment and achievement in reducing road trauma, and to Eric Chalmers and Kidsafe ACT, awarded Australasia's most prestigious road safety award for an exemplary road safety project - the 2017 3M-ACRS Diamond Road Safety Award. We look forward to Eric's plenary presentation on his award-winning work at ARSC2018.
- ARSC2017 also provided the opportunity to recognise outstanding conference presentations, with 7 awardees recognised sharing in \$6,000 worth of awards.
- **SUBMISSIONS:** Over the last 12 months we have presented 3 Submissions. These included - 1) ACRS 2018-19 pre-Budget Submission 2) ACRS 2017 Submission to the House of Representatives Inquiry into Social Issues relating to Land-Based Driverless Vehicles in Australia and 3) ACRS 2017 Submission to Federal Parliamentarians – ACRS Presents the Way Forward. Thanks especially to Martin Small for his help with these submissions – he has been integral in the development of very strong priorities being put forward to our stakeholders.
- **SUPPORTING CHAPTERS:** We are also continuing to support the effectiveness of ACRS Chapters who have also been presenting submissions and running successful events which we will hear about during our Chapter Reports coming up next. Congratulations to all Chapters for their continuing efforts to engage with their regional stakeholder communities in order to improve road safety outcomes.

- **COMMUNICATIONS:** As a major member benefit we have continued to provide regular, informed communications over the past 12 months to members via the following channels:
 - **Quarterly Journal:** Thanks to Chika for the work in pulling together these excellent publications. The journal continues to be a mainstay of College activities and we thank Chika for her continued vision and drive in further ramping up engagement and professionalism standards. Chika is also driving our engagement with the United Nations Road Safety Collaboration of which we have recently been elected a member. I also thank Raph for his continued dedication and skill in overseeing the online submission and review process via Editorial Manager.
 - **Weekly Alert:** 43 Alerts have gone out during the past 12 months.
 - **Media Releases:** 5 have been issued during the past 12 months.
 - **Submissions:** as per above, 3 comprehensive submissions were presented during the past 12 months.
 - **Membership Alerts:** 8 for the year (invitations to comp members etc)
 - **Conference Alerts:** 21 comprehensive Alerts were issued for ARSC2017, and so far 8 have been issued for ARSC2018.
 - **Websites:** we have 3 websites up and running and being updated as often as possible ACRS Website, Conference Website, Awards Website. We are very much looking forward to developing a new website for the College asap, which is budgeted for in our 2019 draft budget to be presented shortly.
 - **Social Media:** We remain active on LinkedIn, Twitter and Facebook – members are encouraged to join and engage with us through these networks.
 - **Photos:** we maintain a comprehensive library of photos from events on Flickr - our album of 2017 conference photos for example has been opened over 2,000 times, and the photo views are sitting at 525,850 which is a fantastic reach.
 - **Videos:** we have added 9 new videos this year to the ACRS Youtube channel

In addition to these highlights and the many more activities that all members are a part of, all Executive Committee members and Fellows are involved in regular ACRS Executive Committee meetings and out-of-session discussions, and I thank you all for your time and expert input – all of which is voluntary.

A huge thank you goes to the ACRS staff here at the corporate office – as you have heard we do a lot with very

limited resources. We have welcomed Kim Day (now Winks) as our Office Manager, who is doing a wonderful job revamping our IT capabilities and financial systems, has refreshed our office space, and is now heavily involved in conference-related work, especially sponsorships.

Including my work which has become full-time, we now have the equivalent of 1.8 Full-time staff in the Canberra office, plus a journal managing editor (Cika), a conference manager (Lexie Duncan from Encanta, based in Melbourne) and a peer-review manager (Professor Raphael Grzebieta who continues to work on our Conference and Journal peer-review system). In total we currently have the equivalent of around 2.7 full-time staff overall.

We continue to have times of increased workload, and with the growth the College is experiencing are looking forward to the strategic review to cement our way forward while being mindful of our heavy reliance on a conference surplus.

To finish up I would like to say a very sincere thank you also to the many people involved in both ARSC2017 & 2018, and now 2019 and 2020 from the Organising Committees to the various sub-Committees, through to our 50 conference editors and over 100 peer-reviewers for each conferences. Our Conferences are certainly the result of a massive collaborative effort from many stakeholders and sectors of the road safety community across Australasia.

And lastly my thanks go to the College President, Lauchlan McIntosh, our Fellows and the Executive Committee, and Chapters who continue to be engaged and committed in this space. In conjunction with our members, all of you continue to see the relevance of our organisation in bringing stakeholders together and providing an independent voice for road trauma reduction advocacy. I would like to specifically say thank you to our outgoing VP, Mr David Healy, who has been a wonderful mentor for me in my role here, and I look forward to David continuing his involvement through the VIC Chapter.

We continue to expand our horizons as evidenced by the engagement with all of our communications, submissions & events. To finish I'll repeat what I said last year as it's still very relevant.....whilst we may receive some push-back in various quarters in terms of advocating for road trauma reductions, we definitely do need to remind ourselves to have 'courageous patience' and perhaps to include 'strategic perseverance' in the mix moving forward.

Thank you for another productive year for ACRS and all our members!

Claire Howe
ACRS *Chief Executive Officer*
8 May 2018

ACRS CEO, CLAIRE HOWE, REPORTS BACK FOLLOWING ATTENDANCE AT THE RECENT MUARC ROAD SAFETY MANAGEMENT LEADERSHIP PROGRAM "EXCELLENT COURSE - HIGHLY RECOMMENDED"

Claire's feedback on the course is as follows, with similar feedback from other attendees noted below:

"What a FANTASTIC course - it's **3 weeks later** and I'm still buzzing from all I have learned, and looking forward to implementing much of what came out of the course for me in my role as CEO of the College.

Thanks so much to the facilitators Eric Howard, Rob Klein, Ian Johnston and Jude Charlton for their expert input and especially for creating such a nurturing, non-threatening environment - so that we all felt comfortable sharing our organisational and personal challenges, and helping each other to develop strategies to overcome them."

More specific feedback included the following:

- Met some great people. Eric, Rob, Jude and Ian were excellent leaders/speakers/mentors. From the start they ensured we were aware that we could challenge them throughout the course (so of course I took that on board!)
- I was the only one there from a Not-for-profit and from Canberra. All other participants were spread across Australasia and 2 from India. In total there were 20 attendees.
- Gender balance was 50/50 and was quite a youthful mix. This was the first time to reach 50/50 apparently and made for a 'different feel' according to the presenters
- We were afforded great opportunities to hone our presentation skills. By the time the course finished I had well and truly overcome my life-long fear of public speaking. My presentation included a summary of College activities seeing as not everyone knew who we were/what we do. By the end of the week all were aware of the role of the College and the conference.
- David Shelton gave the dinner speech - excellent! He's very switched on, emotional intelligence came through in spades and it was clear he would make a good leader in any organisation. Dave spoke on leadership challenges and gave relevant examples, reiterating the importance of building and nurturing a good team. He also noted we must regularly take a 'balcony view' of our organisations from time to time (such as the planned strategic review for ACRS) to ensure innovations are effective.
- Robyn Gardener from VicRoads gave an excellent presentation on the development and implementation





- of the Graduated Driver Licensing System, and Michael Fitzharris on insurance/trauma management - just two examples from many. Bernard Carlon was also excellent, and his honest insights were refreshing, especially from such a high position in government. Jeremy Woolley also (as usual) was a standout presenter on the importance of safety planning and design of infrastructure. We all had our ‘cone of silence’ on, so felt safe sharing personal insights amongst the group and presenters/facilitators. The course included a huge amount of interesting information, including for example on the ‘aggressivity’ of vehicles (not taken into account in vehicle star-ratings), as well as the insurance system in TAC/NZ’s ACC compared with others. There’s so much great work already happening that needs more exposure and replication, plus the opportunities left to make improvements are endless. This course was *extremely* motivating in that regard - perfect learning for the College and our future conferences.
- I personally gained a very useful perspective on the ‘bottom up’ approach to supporting the NRSS and the various jurisdictional strategies. This included advice to start to ‘veer away from asking whether you can/should do it’, and simply do it. One of the beauties of the College is that we are not so constrained with complex processes and procedures, something I am hopeful we don’t lose with our restructure. The bottom up approach is especially useful for our work across Chapters, so I can see this being of real benefit to all of us.
- NZ rep, Nic Johanssen, and I made progress on activating the NZ Chapter in conjunction with our NZ Chair Paul Graham. Excellent opportunities there, particularly with the increased trauma levels they are experiencing and the recent change of government.
- The organisers are very keen to work the course in to dovetail with the annual ARSC conference - what an excellent idea. I personally think all attendees would benefit from the course at some stage in their careers - federal, state, local, academics, police, economists, health professionals....the whole gamut!

“My personal challenge was how to keep my ‘head above water’ while the College keeps moving onward and upward, and while we are experiencing such significant growth in profile, turnover and workload. Group discussion resulted in the following excellent ideas which I plan to progress asap:

- Perfect course, perfect timing for me!
- Despite the looming ACRS strategic review, political issues, uplift in profile and external desirability to be involved in College direction etc.....implement URGENT recruitment to support my role
- Single point of failure is immediate issue - me – e.g. today!
- Recruit consultant for strategic review
- Survey members & stakeholders

- Current role analysis – all roles
- Align future direction (with support) with my values and objectives.”

Feedback from other May/June 2018 course participants:

“As an Operations Commander, I found the course broadened my perspective considerably on improving all road safety aspects to help save lives and reduce trauma.”

Acting Assistant Commissioner David Johnson
Road Policing Command
 Queensland Police

Memorable quotes

1. *“The worst thing you can be accused of is trying to save too many lives” Eric Howard in the context of pushing safety hard.*
2. *“Our obsession with speed is only matched by the Americans obsession with firearms” Stuart McGregor*
3. *“An intelligent system observes itself”*
4. *“Take the energy out of the system and put it back into your energy”*

Mr Niclas Johanson
Senior Manager - Internal Practice
 New Zealand Transport Agency

“I spent the week in Melbourne away from my loved ones to ultimately look after my loved ones. Embedding the safe system mindset in those that I engage with so that it sticks in their hearts is key to achieving leadership growth in road safety.”

Diane Aho
Executive Manager - State Traffic Research & Projects
 Western Australia Police Force

“The MUARC course gave me an opportunity to meet colleagues from all over Australia and the world, who are working to improve road safety in their role. Together we learnt about the safe systems approach to managing road safety and the importance of adaptive leadership to achieve change. I’ve built my networks and my capacity to tackle the issues that I face each day in my role.”

Melissa O’Brien
Manager - Productivity, Safety and Environment
 National Transport Commission

This training is the best I’ve ever attended and it will have a lasting impact on me along with my future aspirations

It highlighted the importance of the need for a Safe Systems approach in relation to all aspects of road safety

Zero serious injuries and deaths is achievable, however we all need to do our part

I can, (and will,) make a difference in improving road safety, (as we all can.)

We need to keep 'chipping away' in relation to road safety improvements - there will be challenges and need to be persistent!

Josh Lewis

Team Leader - Road Safety and Traffic Engineering
VicRoads

"I highly recommend the MUARC Road Safety Leadership Program to any road safety commander or practitioner in any policing jurisdiction across Australia or internationally.

I found the Program to be extremely valuable in outlining the 'science' of enforcement in Safe Systems. The research underpinning road safety enforcement strategies and tactics was eye opening. Too often police are taught how to do something, but not 'why'. The Program gives police the 'why'. I can't recommend it highly enough."

Simon Maund

Region Traffic Tactician - Traffic and Highway Patrol Command
New South Wales Police

Background - The intensive 5-day Program

The program content addressed road safety leadership and management challenges faced in Australia and internationally, in responding to circumstances that apply in high, low and middle income countries. Drawing upon presenters with extensive international experience in these environments, it comprised an intensive process of formal presentations, interactive case studies, group work and panel discussions conducted over five days at the Monash University Law Chambers in Melbourne's CBD.

A strong feature of the program is its integration of road safety management, science and leadership topics. It has been designed to ensure an interactive and dynamic engagement between the teaching team and program participants that works through best practice science and its potential application for improved road safety results. It then shifts to a deeper appraisal of the contemporary leadership and management challenges raised and how they can be met to enable effective implementation which will actually deliver the desired results.

Through the program's well-structured and intensive learning process, participants gain an in-depth understanding of:

- The core elements of the road safety management system;
- The scientific evidence base and technological innovations that underpin effective road safety interventions and related public policy challenges;
- How to introduce effective change;
- The personal qualities required to improve leadership capability; and
- How to engage with and influence internal and external stakeholders to successfully address leadership challenges.

The learning process for participants continues on their return to work, and they will benefit from their ongoing peer-to-peer relationships with fellow participants and program mentors. In this way, the Road Safety Management Leadership Program builds informed and innovative communities of practice that strengthen organisational leadership capacity and contribute to the achievement of improved and sustainable road safety results.

Program benefits

Participants gain access to the extensive knowledge and real-world experience of the internationally-renowned teaching team. Registration is a highly-valuable investment for road safety organisations, with the program accelerating the professional development of road safety managers by strengthening their organisational leadership effectiveness and supporting their longer-term development through a mentoring network and ongoing program initiatives. The program delivers immediate and ongoing benefits to participants and the organisations they represent by addressing the management and leadership dimensions - along with the science underpinning them - that are vital to ensuring sustained success. The diversity of participants fosters a comprehensive understanding of the challenges and opportunities shared by road safety managers across agencies and cultures, and offers a shared vision towards a safe system approach.

Find out more about the course on the MUARC Website
<https://www.monash.edu/muarc/news-and-events/events/leadership>.

Diary

17 – 21 September 2018

25th ITS World Congress
Copenhagen, Denmark
<https://itsworldcongress.com/>

19 – 22 September 2018

15th Romanian National Congress of Roads and Bridges
Lasi, Romania
<http://www.apdp.ro/en/>

26 – 29 September 2018

Global NCAP World Congress
Delhi, India
<http://www.globalncap.org/global-ncap-host-first-world-congress-delhi-september-2018/>

3 – 5 October 2018

Australasian Road Safety Conference
Sydney, Australia
<http://australasianroadsafetyconference.com.au/>

8 – 12 October 2018

Walk21
Bogotá, Colombia
<https://www.walk21.com/>

15 – 17 October 2018

6th International conference on driver distraction and inattention
Gothenburg, Sweden
<http://ddi2018.org/>

29 – 30 October 2018

20th International Conference on Road Traffic Safety and Public Transport Vehicles
Paris, France
<https://www.waset.org/conference/2018/10/paris/ICRTSPTV/home>

5 – 7 November 2018

Safety 2018 World Conference
Bangkok, Thailand
<http://www.worldsafety2018.org/>

Peer Reviewed Papers

Original Road Safety Research

Recording of alcohol in official crash statistics: underreporting and procedures to improve statistics

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Key Findings

- Official statistics on alcohol-related road casualties are often misleading due to underreporting.
- Improvements are needed to reach more accurate and reliable statistics on drink driving and this study makes recommendations to achieve this.
- Harmonized definitions are the necessary basis for improvements.
- All countries that use only police statistics should find methods to correct underreporting of alcohol-related crashes and casualties.

Abstract

Worldwide 1.25 million people die in road crashes every year and it is widely recognized that drink driving is an important risk-increasing factor. Official statistics of alcohol-related crashes are likely to underestimate alcohol-related crashes and casualties, because official statistics are affected by underreporting. This study aims to obtain a good insight into the definitions, legislations and reporting procedures of alcohol-related road casualties to reach an accurate estimate of the drink driving problem and recommendations on how to improve the reliability and comparability of official statistics. A total of 45 countries, represented by road safety experts, responded to an online questionnaire. The questionnaire consisted of questions divided into four main categories: drink driving legislation, definitions of alcohol-related road casualties, recording methods, quality of official statistics and experts' best estimates. A weighted average of 21.8% alcohol-related road deaths is found in official statistics in the group of 45 countries and this proportion remains constant between 2000 and 2010. There are first signals that the proportion in 2015 is lower than in the period 2000-2010. If the proportion of 21.8% applies worldwide and is based on 1.25 million road fatalities per year, the annual number of alcohol-related road deaths will be around 273 000. However, this number is an underestimate of the real problem because strong indications of underreporting of alcohol-related crashes in official crash statistics are found. Most countries (89%) still base their official data upon only one single data source and in most cases (87.5%) these are the police records for which this study found evident shortcomings. Furthermore, countries use different definitions which makes international comparison difficult.

Keywords

Alcohol, drink driving, casualties, statistics, underreporting

Introduction

The World Health Organization (2015) reports that worldwide there are 1.25 million road deaths occur per year and WHO concludes that this number has not changed much since 2007. One important road safety issue is drink driving and it is well documented that drink driving increases risks (Keall et al. 2004; Blomberg et al. 2005; Hels et al. 2011). National official percentages of alcohol-related road fatalities vary widely between 2% and 38% of all road traffic fatalities (WHO, 2013; WHO, 2015). Many studies suggest that the official numbers of alcohol-related road casualties are probably not reliable due to the problem of general underreporting of road crashes (Derriks and Mak, 2007; ETSC, 2010; IRTAD, 2011), and, more specifically, due to underreporting of alcohol-related road casualties (Assum and Sørensen, 2010; COWI et al., 2014). In the present study we describe how countries arrive at their national drink driving statistics and how some countries focus on methods to counter the problem of underreporting to improve the official numbers on alcohol-related road casualties so as to present a realistic estimate of alcohol-related crashes.

Underreporting

Underreporting of alcohol-related road crash casualties in official crash statistics is a widespread phenomenon and has several causes. First of all, not all countries systematically test blood alcohol concentration (BAC) of all road users involved in road crashes and in some countries legislation does not allow post mortem testing. Sometimes police officers decide not to make an alcohol test from piety to those left behind. Furthermore, data collection is sometimes associated with a lot of (paper)work, is seen as just an administrative burden and is therefore not carried out (IRTAD, 2011). In addition, recordings of alcohol test results sometimes get lost in the process of registration (Derriks and Mak, 2007) and police officers at the scene of

the road crash have a tendency to underestimate high BAC (Gundy and Verschuur, 1986) and may therefore decide not to test for alcohol. Finally, it can not be excluded in some countries that political or religious reasons prevent a proper registration of alcohol-related crashes.

To overcome the problem of underreporting of alcohol-related road crashes in the police registration, countries use other sources such as hospital data on road crash casualties to supplement the police data (IRTAD, 2011). For a better understanding of both the injury severity and the total number of alcohol-related road casualties, the use of hospital data in addition to police data is very important and contributes to better international comparisons (IRTAD, 2011).

In addition to the data on alcohol-related crashes surrogate sources can be used for better estimates of real numbers of alcohol-related fatalities and injuries. For example, a previous study on the effects of different scenario's on alcohol interlock programmes in the European Union (COWI et al., 2014) concludes that an estimated 20-28% (25% average) of all road fatalities in Europe were related to alcohol use, whereas the official statistics for the same group of countries suggest an average of 12.9%.

Defining an Alcohol-Related Crash

Another problem concerns the definitions of alcohol-related road casualties used in the registration methods and their differences between countries. These differences complicate meaningful international comparison of official data on alcohol-related road crash casualties. In order to harmonize the recording of alcohol-related fatalities, the European SafetyNet project (2008) recommended the following definition for an alcohol-related fatality: "Any death occurring within 30 days as a result of a fatal road crash in

which any active participant was found with a blood alcohol concentration level above the legal limit". The choice of 30 days is based on the international definition of a road crash fatality (UNECE, 2009; IRTAD, 2012; WHO, 2013). However, the definition does not account for pedestrians and cyclists as active participant above the legal limit, since most countries have no legal limit on BAC for these groups. Therefore the absence of these road users in the definition of an alcohol-related fatality also contributes to the underestimation of drink driving fatalities in road traffic.

Methods

As described above, the problem of underreporting in alcohol-related crash statistics and the difficulties of making meaningful international comparisons on drink-driving data are well-known issues. In order to arrive at reliable and accurate numbers on alcohol-related road casualties worldwide the main contributors to underreporting have to be unmasked first. Therefore, the main objectives of this study were to identify critical elements that cause underreporting and, secondly, to identify existing methods that could be used to counter underreporting and improve the reliability and the comparability of the official crash statistics on drink driving. This was done by distributing an online questionnaire among a large number of countries that included questions on their recording methods, data sources, definitions and current legislations.

Respondents

This study was part of the work programme of the International Traffic Safety Data and Analysis Group (IRTAD, 2018). With the help of the secretariats of the IRTAD Group and the Ibero American Road Safety Observatory (OISEVI) respondents from 54 countries were selected. From these 54 representatives a total of 45 countries filled out the questionnaire. Most respondents were representatives of the IRTAD group (see Table 1). IRTAD is a group of road safety specialists with a focus on collecting and analysing road safety data. IRTAD has more than 70 members from almost 40 different countries. IRTAD works under the umbrella of the International Transport Forum ITF. ITF is politically autonomous and is administratively integrated with the OECD in Paris.

Table 1. Responses of countries by organisation membership in percentages

	Response		No response		Total
IRTAD (34)	34	100%	0	0%	63%
OISEVI (16)	8	50%	8	50%	30%
ICAP (4)	3	75%	1	25%	7%
Total	45	83.3%	9	16.7%	100%

OISEVI could be considered as a daughter of IRTAD. OISEVI is, like IRTAD, a network of road safety experts (in Latin America) and a database. Twenty countries are

member of OISEVI (19 from Latin America plus Spain). IRTAD hosts the OISEVI database. ICAP (International Center for Alcohol Policies) is an organisation set up by the beer, wine and spirit producers. I ran several programmes to reduce drinking and driving. The organisation has changed its name in IARD (International Alliance for Responsible Drinking).

The country representatives are all road traffic (safety) experts: 38% of which work for national research institutes, a quarter for the national road safety authority and approximately 20% work for the Ministry of Transport. The majority of respondents are researchers or statisticians (44%) and managers or directors (36%).

Procedure

The country representatives where asked to participate in this study by an invitation letter which contained a web link to the online questionnaire. The initial questionnaire was pre-tested with the help of five road safety experts from the IRTAD network who did not participate in the final questionnaire. Based on their remarks some questions were added and some were reformulated. The first group of respondents that were approached are IRTAD members whose responses were collected between March and June 2014. The second group of respondents are members of OISEVI and are from Spanish speaking countries in Latin America. Therefore the questionnaire was translated into Spanish. These respondents were approached in mid-April 2014. A third group of respondents consisted of representatives from six countries participating in a project of the International Center for Alcohol Policies (ICAP). Two of these countries, Colombia and Mexico, are also members of the OISEVI group. In fall 2014 and autumn 2015 some countries were once more approached via e-mail for some additional follow-up questions regarding their responses and to enquire about additional methods used to improve drink driving data. In February 2017, those respondents who reported on their countries' national statistics in the initial questionnaire were sent a request to share their official statistics on alcohol-related casualties for the year 2015.

Questionnaire

The online questionnaire was developed and distributed by using an online questionnaire application LimeSurvey (v2.05). The questionnaire (see Annex B in IRTAD, 2018) included four main topics:

- General background information on the respondent
- Legislation on BAC, definitions of alcoholrelated road casualties, and official casualty data.
 - Definitions used as a basis for the official data on alcohol-related road fatalities and serious road injuries.
 - Definitions of road fatalities and serious road injuries attributable to drink driving.
 - Unit of measurement for the legal BAC limit.
 - Existence of differentiated legal limits for the

- general driving population and other driver groups such as novice or professional drivers.
- Changes in national legislation regarding drinking and driving in the period 2000 to 2010.
- Official statistics on the number of road fatalities and serious road injuries related to alcohol in 2000, 2005 and 2010, thus covering a time period of ten years. It was a predetermined choice not to ask for official data on more recent years since often these numbers are not yet (completely) available.
- Method of recording alcohol-related crashes by police and medical institutions
 - Procedures used to produce police reports on road crashes.
 - Conditions and protocol for carrying out alcohol tests on the scene of the crash.
 - Conditions and protocol for carrying out alcohol tests at hospitals.
 - Availability of standard tests.
 - Process for registering results of alcohol tests.
 - Linkage procedure to link hospital and police data.
- Quality of the data and the respondent's expert estimate on alcohol-related road casualties
 - Existence of procedures to link and combine police data and hospital data on serious road injuries to correct for underreporting.
 - Conditions for post-mortem testing.
 - Expert's best estimate of the proportion of road traffic deaths and serious road injuries attributable to drink driving.
 - Expert's comments on differences between the reported official data and their personal best estimate.
 - Drug-related fatalities and injuries with a distinction between illicit and prescribed drugs.

The questionnaire mainly consists of closed questions, mostly with more than one possible answer. The researchers checked responses (with information from other sources) and corrected, if needed, together with the respondents. Data imputation for missing data was not needed.

Results

Legislation

Nearly all representatives (96%) reported to have a legal alcohol limit in their country. These legal limits vary between 0.0 g/l and 0.8 g/l for the general driving population. Countries use different units of measurement for BAC in their legislation on drink driving. Of the 45 respondents, 22 (49%) reported to have a lower legal limit

for young or novice drivers, 23 (51%) reported to have a lower legal limit for professional drivers and of the 45 representatives, 19 (42%) reported to have lower legal limits for both young or novice drivers and professional drivers. However, countries use different definitions for a professional driver and for a young/novice driver. Regarding the legal BAC limit, we found a trend towards stricter legislation on drink driving. Twelve of the 45 countries (27%) lowered their legal BAC limits for the general driving population and 11 countries (24%) introduced or lowered BAC limits for the young novice drivers and the professional drivers.

Definitions

Another finding was that different definitions of alcohol-related road fatalities and serious road injuries were reported by the 45 respondents. The majority of the countries (62.2%) define an alcohol-related fatality as "any death occurring within 30 days as a result of a fatal road crash in which any active participant was found with a blood alcohol level above the legal limit." The United States is the only country that does not use 'any active participant above the legal limit' in their definition, but only includes drivers (of motorized vehicles) and motorcyclists. This country does not have legal limits on alcohol for pedestrians and cyclists and the SafetyNet definition would therefore not apply for these groups. A minority of the countries (26.7%) use other definitions which in most cases do not include a time period and 11.1% do not have any definition on alcohol-related road fatalities at all.

There is no generally accepted definition of alcohol-related serious road injuries. This study distinguishes between a so-called complete and an incomplete definition. The complete definition includes both a definition on serious road injuries and on whether or not the crash is alcohol-related. 24.4% of the countries are found to use this 'complete definition', but these definitions still vary considerably. 11.1% have an 'incomplete definition' because they do not specify the severity of an injury (severe or slight) and the majority (64.5% countries) do not have any definition at all.

Official Statistics

Data was collected for 2000, 2005 and 2010. Of 45 countries 37 (82%) were able to provide official information on alcohol-related road fatalities (Figure 1) and 25 (56%) for alcohol-related serious injuries (Figure 2). Looking at the development over the years 2000-2010, 16 countries have an increased proportion of alcoholrelated fatalities (see Figure 1). In 2010, the proportion of alcohol-related fatalities ranged from approximately 5% to 35% and in 10 countries more than 30% of road fatalities were alcohol-related. In general, the proportion of alcohol-related fatalities in official statistics has remained stable over the years. The weighted average in 2000 was 21.95% and in 2010 this remained on the same level with a weighted average of 21.8%. If we project this proportion on the annual number of 1.25 million road fatalities worldwide, the number of alcohol-related deaths is around 273 000 worldwide.

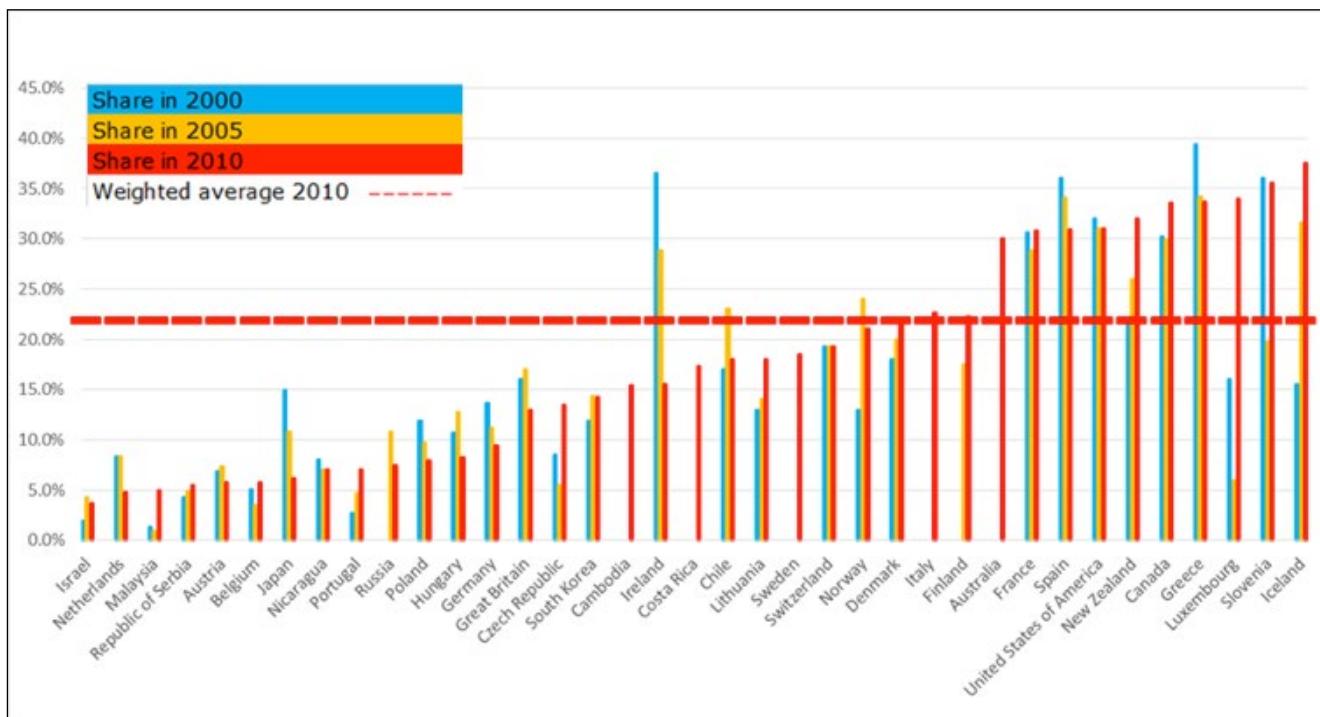


Figure 1. Proportion of alcohol-related road fatalities in 2000, 2005 and 2010 from official statistics

As expected the proportion of alcohol-related serious injuries is lower than the proportion of alcohol-related fatalities because of the higher risk of being involved in a fatal crash due to drink driving. The average proportion (mean) remained quite stable between 2000 (12.3%) and 2010 (11.3%). The highest proportion of alcohol-related serious road injuries for 2010 are found in New Zealand (23%) and Greece (23%) and the lowest proportion is reported in Japan (1.6%), see Figure 2.

Because legal alcohol limits differ between countries, alcohol-related casualties (defined as above a legal limit) will be derived using different ‘base lines’ (for example in UK alcohol-related casualties starts from a legal limit of 0.8 g/l and in Hungary from 0.0 g/l). This complicates international comparisons. Furthermore, many countries apply specific (lower) limits for professional drivers and for young/novice drivers.

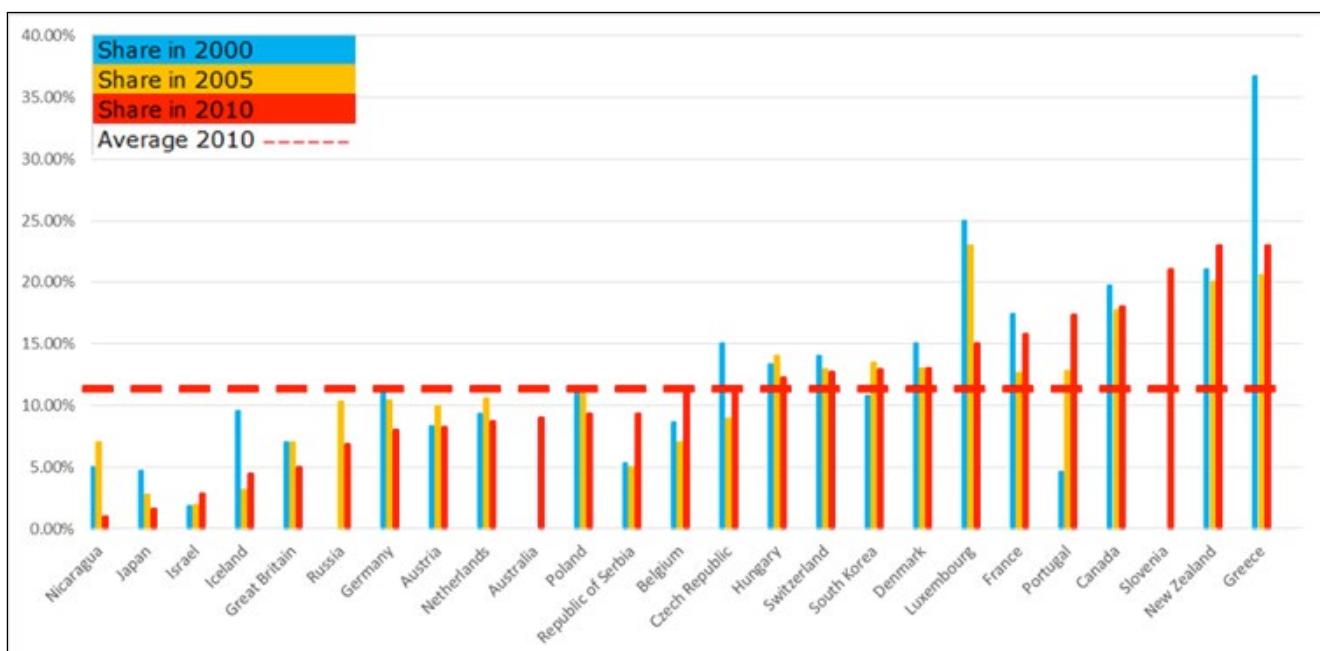


Figure 2. Share of alcohol-related serious road injuries in 2000, 2005 and 2010 from official statistics

Early 2017 another request was made to the respondents from 45 countries asking about alcohol-related casualties in 2015. The new information they provided was not fully comparable with info from earlier years (2000, 2005 and 2010), but it suggests a lower proportion of fatally injured casualties than in the earlier years, but no change for serious injuries.

Data Collection Methods and Sources

The vast majority of countries use police records as their primary data source for statistics of alcohol-related fatalities (80%) and serious road injuries (87.5%). Only six countries make use of another data source in addition to the police records such as hospital data, insurance data and forensic records. However, only in three of these six (Russia, the United States and Sweden) two types of data (police and other) are reported.

An important reason for the police force to carry out an alcohol test is their suspicion of alcohol consumption above a legal limit among the road users involved in a crash. On the other hand, lack of suspicion is the main reason for the police not to carry out an alcohol test. In more than one-third (38%) of the countries alcohol tests are not performed at a later point in time if testing at the scene of the crash is not possible. If tests are carried out later, in most cases this is done in a medical institution. However, in only four countries (Argentina, Cambodia, Russia and Serbia) the official data is based on hospital data in addition to police records. Another method to limit underreporting is post-mortem testing. In 32 countries (71%) legislation allows post-mortem tests on alcohol consumption, but in 10 of these countries post mortem tests are not always carried out because of various reasons (permission of the relatives is needed, test is performed only upon request of the prosecutor, and family concerns).

Experts' Best Estimate

In addition to the official data on alcohol-related serious road injuries and fatalities the respondents were asked for their own (experts') best estimate on the proportion of alcohol-related fatalities in their country. Eighteen of the 45 country respondents (40%) indicate that the official data on alcohol-related road casualties is the best estimate. Great Britain, The Netherlands, Serbia, Russia and Switzerland make a best estimate which is higher than the official data of their country. Two respondents (4.4%) make a personal best estimate that is actually lower than the official figure on alcohol-related road casualties (Chile and Nicaragua). Unfortunately, the largest proportion of respondents (44%) either do not have official data or a best estimate, therefore making a comparison between the two impossible. More respondents provide best estimates on fatalities than on serious injuries, which is in line with the general availability of data.

Methods for Adjusting the Official Number of Alcohol-Related Road Casualties for Underreporting

Only a very limited number of countries (for example Canada, France, the Netherlands, UK, USA) are aware of the problem of underreporting of alcohol-related crashes and have developed methodologies to adjust official numbers (IRTAD, 2017). These methods differ for road fatalities and serious road injuries, and the methodologies are country-specific so they also differ between these five countries. With regard to the improvement of the estimate on alcohol-related road fatalities, methods range from strict quality control procedures for recording by the police (France; ONISR, 2012), the use of witness statements and police officers' indication on alcohol use at the scene, imputation techniques (The United States; Klein, 1986; Rubin, Schafer & Subramanian, 1998 and the United Kingdom; DfT, 1989), or using the development for alcohol use among serious road injuries to estimate the number of alcohol-related road fatalities (The Netherlands; Houwing et al., 2014).

Methods applied to estimate the number of serious road injuries vary between the use of in-depth studies in hospitals (Isalberti et al., 2011), combining the trend of alcohol use in traffic with information on risks of serious injury for various BAC levels (The Netherlands; Houwing et al., 2014), using the trend for fatal injuries to estimate the number of alcohol-related serious road injuries (The United Kingdom; DfT, 1989) and using a surrogate measure such as including serious injuries in single-vehicle crashes that occurred at night (Traffic Injury Research Foundation of Canada, 2010).

Discussion

The WHO (2013) found a wide range of proportions of alcohol-related road fatalities among countries (between 2% and 38%), which is confirmed in this study with proportions of officially reported alcohol-related fatalities ranging from 5% to 35%.

Based on official statistics of countries that responded to our survey, more than 20% of all fatalities (weighted average 21.8%) are alcohol-related. This proportion remains constant over the years 2000-2010. We conclude that this official number is a serious underestimate because official statistics suffer from underreporting of alcohol-related crashes and casualties. Moreover, this proportion does not include pedestrian and cyclist fatalities and serious injuries in alcohol-related crashes. Therefore, if we assume that the estimate of 25% on alcohol-related road fatalities as estimated for Europe (COWI et al. 2014) is a good estimate for all countries worldwide and we use 1.25 million annual road fatalities worldwide as a basis, the alcohol-related road toll can be put at around 313 000 deaths every year. The official data of the countries surveyed for this study show that a weighted average of 21.8% among road deaths. Accepting the 21.8% from this study as a reasonable estimate for all countries in the world, the alcohol-related deaths among fatally injured road users can be put at around 273 000 people every year.

But these numbers are an underestimate of the real numbers. In accordance with previous work (COWI et al. 2014; IRTAD 2011; Assum and Sørensen 2010; ETSC 2010; Derriks and Mak 2007) we identify underreporting as a major problem in determining the correct number of alcohol-related road casualties. The majority of the countries surveyed base their official data upon the police recordings only, for which this study found evident shortcomings. Furthermore, different countries use different legislations on BAC and various definitions of what constitutes a road crash casualty. These deficiencies in data collection and the finding that post-mortem tests are often not performed, negatively influence the accuracy and reliability of the official data regarding alcohol-related road casualties, thus leading to underestimated figures. Therefore, relying on official statistics will often be misleading. To enable more accurate analyses improvements are needed and recommended.

Recommendations

To identify and limit underreporting of alcohol-related crashes it is recommended that the police force carry out systematic and 100% alcohol testing of all road users actively involved in all serious road crashes (fatal crashes and crashes with serious injuries). Furthermore, we recommend conducting additional investigation to assess underreporting and, when necessary, to apply correction factors to estimate “real numbers”. If this is not a realistic option, it is recommended to estimate the number of alcohol-related road fatalities by using additional statistical analysis methods.

To make official country statistics comparable, definitions of alcoholrelated road casualties should be harmonized. It is recommended to define an alcohol-related road fatality as “any death occurring within 30 days as a result of a fatal road crash in which any active participant was found with a blood alcohol level above the legal limit”. A person seriously injured in an alcohol-related crash should have injury of the severity level of 3+ (IRTAD, 2011) on the Maximum Abbreviated Injury Scale (MAIS3+), so that it would be defined as “any serious injury at MAIS3+ that occurred as a result of a road crash in which any active participant was found with a blood alcohol level above the legal limit”. If countries are unable to apply these recommended definitions, they are invited to develop algorithms to allow for a conversion. We recommend applying adequate conversion factors (or algorithms) in case of different BAC legal limits that would allow meaningful international comparisons.

In order to make sure the recommended definitions apply for all road users involved in alcohol-related road crashes, (i.e. ‘any active participant with a blood alcohol level above the legal limit’) countries need to introduce legal limits on alcohol for pedestrians and cyclists. If they fail to do so, these vulnerable road user groups will not be recorded as an alcohol-related road casualty because there is no legal limit. This lack of legal limits for these user groups contributes to the issue of underreporting. It is therefore recommended that future research investigates if legal limits for pedestrians and cyclists are practicable, for example in terms of

enforcement. Future work should also study which legal limits on BAC should be applied for these groups. The other option is of course to modify the definition of alcohol-related road crashes.

Acknowledgements

This study is carried out with the indispensable help of many. We gratefully acknowledge the help from both the IRTAD and the OISEVI Secretariats. We especially thank Veronique Feypell, for her advice in and the distribution of the questionnaire to all the IRTAD-members. The help of Corina Puppo and Virginia Alvarez in translating the survey into Spanish and distributing and collecting the questionnaire and responses for the OISEVI-members is highly appreciated. Klaus Machata, David Silcock, Kathy Stewart and Pilar Zori are also gratefully acknowledged for their recommendations on the initial draft of the survey. We also thank Horst Schulze and once more Kathy Stewart for their critical views on earlier drafts. Finally, our acknowledgements go to Hansje Weijer of SWOV for her help in making this paper readable.

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Analysis of trends in the composition of Australasian vehicle fleets associated with pedestrian injury severity

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Key Findings

- Pedestrians are very vulnerable to injury when impacted by a vehicle: policy and regulation around vehicles and fleet composition must therefore consider their safety
- Increases in sports utility vehicles (SUVs) and light commercial vehicles in Australasian fleets will have decreased pedestrian safety
- However, newer vehicles pose less risk than older vehicles for pedestrian severe and fatal injury
- Trends in the vehicle fleets show this last effect will have reduced injury severity levels much more than the effects of more SUVs and light commercial vehicles in the fleet

Abstract

Australasian fleets have changed substantially over the past decade, with SUVs and light commercial vehicles becoming more popular. These vehicles have been shown in other studies to impose higher fatality risk to pedestrians. For newer vehicles, pedestrian safety may also benefit from international New Car Assessment Program protocols and safety regulation. To quantify such vehicle fleet effects on pedestrian injury severity, this paper analyses pedestrian injury outcomes using Australian crash data. Younger drivers (aged 25 and under) and male drivers were associated with higher severity pedestrian

injury. Collisions with commercial vehicles (vans and utility vehicles) and SUVs were associated with higher odds of fatal and serious pedestrian injury than collisions with cars, which is likely to be related to their frontal structure configuration. There was a trend towards better injury outcomes when the vehicle had a more recent year of manufacture, consistent with – but not necessarily attributable to – changes in vehicle design. Trends over the past 15 years were also assessed using crash data from New Zealand and five Australian States. All other factors being equal, increasing proportions of SUVs and commercial vehicles in these fleets will have increased pedestrian injury severity risks. Nevertheless, this was more than counterbalanced by a reduction in injury severity associated with newer vehicles entering the fleets. The strong effects of vehicle factors found in our analysis support assessment protocols and safety regulations that measure the impact of vehicle frontal structure design on pedestrian injury outcomes.

Keywords

Pedestrian; injury severity; vehicle safety standards

Introduction

Globally, more than one third of the 1.2 million annual road fatalities are pedestrians (WHO, 2009). Pedestrian injury is particularly important in countries with high levels of pedestrian activity, which are generally low-income countries with relatively low levels of motorisation. In low-income countries, around 54% of road fatalities are pedestrians and cyclists, compared to an average of about 23% in high-income countries (Naci, Chisholm, & Baker, 2009). In Australia, 182 pedestrians were killed in 2016, constituting 14% of the road toll (BITRE, 2017); the corresponding figure for New Zealand in 2016 was 25, 8% of that year's road toll (NZ Transport Agency, 2017).

There has been a growing recognition that the design of vehicles, particularly the frontal structures that impact on pedestrians and cyclists, plays an important role in injury outcomes for unprotected road users (Hu & Klinich, 2012). Injuries to the pedestrian can be caused by impacts with the vehicle, the road, or both. Analysis of pedestrian injury using US data has shown that in 80% of cases studied, the primary mechanism in producing pedestrian injuries was the impact with the vehicle (Zhang, Cao, Hu, & Yang, 2008). Despite this, there are currently no Australasian vehicle safety regulations specifically aimed to minimise the risk of injury to unprotected road users apart from some general requirements specified in Australian Design Rule 42/04 (Office of Parliamentary Counsel, 2005). However, the New Car Assessment Programs in Australia (from 2000), Europe (from 1997) and Japan (from 2003) all include pedestrian protection tests. From 2011 the ANCAP Roadmap (ANCAP, 2018) has required at least minimum pedestrian protection for vehicles to achieve five stars, and this required minimum level of protection has been increased periodically since then. Standards have been adopted in Japan and the European Union (United Nations Economic Commission for Europe, 2008) to promote the design of safer front-end structures for impacts with unprotected road users. As given makes and models are mass-produced for a variety of markets internationally, the establishment of these testing protocols and regulation standards will affect the safety characteristics of vehicles intended for the international market (Hu & Klinich, 2012), which include most popular car models. Analyses of pedestrian injuries have shown that the head and lower extremities are the most commonly injured body regions, which is the rationale for these regions to be the sole focus of the pedestrian impact-test procedures

(Hu & Klinich, 2012). Favourable pedestrian impact-test scores arise from front-end structures able to effectively absorb the energy of an impact with a pedestrian, focusing on these key body regions.

Vehicle aggressivity ratings measure the injury risk that a vehicle poses to road users other than its own occupants (including other vehicle drivers, pedestrians, motorcyclists and bicyclists) in a collision (Newstead, Keall, & Watson, 2011). The Australasian Used Car Safety Ratings vehicle safety rating system includes a measure of relative vehicle aggressivity defined as the risk of death or serious injury to the other road user given crash involvement. Initially, two discrete indices were developed in the Australasian system for vehicle drivers and unprotected road users (pedestrians, cyclists and motorcyclists) (Cameron, Newstead, & Le, 1999). This was later combined into a single index incorporating both other vehicle drivers and unprotected road users (Newstead, Watson, & Cameron, 2006). The current study focuses on an analogous pedestrian aggressivity measure, which is the relative rate of a fatal or serious (hospital admission) injury to a pedestrian given that the pedestrian has sustained some level of injury in a collision with the vehicle. A high value for this measure, all other things (including impact speed) being equal, indicates a poorly performing vehicle. Higher values should coincide with vehicle front-end structures that are relatively unforgiving, are geometrically unfavourable with respect to pedestrian impacts or promote unfavourable pedestrian dynamics in the collision.

As the forces imposed on an impacted pedestrian increase with vehicle speed, any attempt to assess vehicle-related factors contributing to pedestrian injury severity should take this into account. Accurate information on impact speeds is rarely available, so proxies must be used, such as the speed limit of the crash site and characteristics of the driver. Drivers' speed choice is clearly important in determining impact speeds, which is related to the age and gender of the driver. For example, crashes involving young drivers have been found to be more likely to have excessive speed as a factor, and more so for young males (McGwin & Brown, 1999). Characteristics of the pedestrian are also likely to have an effect on injury severity. It is well established that because of their greater fragility, older people are more likely to die (Evans, 2001) or to be injured (Keall & Frith,

Table 1. Variables used in models estimating associations between pedestrian injury severity and driver, pedestrian and vehicle characteristics

Variable	Values
Injury severity (outcome variable)	=1 if pedestrian fatally injured or admitted to hospital =0 otherwise
Pedestrian Age	0-9; 10-25; 26-59; 60 plus
Driver Age	up to 25; 26-59; 60 plus
Pedestrian Sex	Male; Female
Driver Sex	Male; Female
Speed limit	Up to 80km/h; 80km/h plus
Year of manufacture	1982-2012
Vehicle type	Car; SUV; light commercial vehicle
State	Victoria, Queensland, South Australia
Year of crash	2010, 2011, 2012
State*year of crash	(interaction between the above variables)

2004) when in car crashes. An analogous steep increase for older people in the probability of fatal pedestrian injury has also been found (Kim, Ulfarsson, Shankar, & Kim, 2008)

Given the importance of pedestrian injury and their vulnerability in crashes, there is a need to identify factors that lead to more severe pedestrian injury if suitable countermeasures are to be implemented. This study analysed crashes involving pedestrians to identify factors associated with reduced injury severity, and looked at how trends in Australasian vehicle fleets are likely to affect trends in pedestrian injury severity levels.

Methods

Data

Pedestrian injury data matched to information on the driver and the vehicle involved were analysed from the Australian States Victoria, Queensland and South Australia, covering vehicles manufactured over the period 1982-2012 and crashing during the years 2010-2012. Only crashes involving cars, SUVs and light commercial vehicles were included. Injuries not occurring on public roads, such as pedestrians injured on driveways that are private property, were not analysed as they are not officially within the scope of the crash surveillance systems. Also excluded were crashes where more than one vehicle was involved, as the role of vehicle characteristics in resultant injury outcomes is more complex to infer. In aggregate, there were data for 4,416 pedestrians, 52% of whom were fatally or seriously injured.

Vehicles were classified either from VIN numbers (obtained by matching the crash data to registers of licensed vehicles) or from detailed make and model descriptions into three types: cars; SUVs; light commercial vehicles (vans and utility vehicles – sometimes referred to as pickup trucks in the US).

The second stage of analysis, which evaluated changes in the composition of Australasian crash fleets over time, was conducted on data from 2.6 million crash-involved vehicles from the Australian States New South Wales (NSW), Victoria (VIC), Queensland (QLD) and Western Australia (WA) together with New Zealand (NZ) for the years 2001 to 2015. Aspects considered were the average year of manufacture of crashed vehicles, the proportion of the fleet that consisted of SUVs and light commercial vehicles, and finally, the prevalence of young drivers and male drivers involved in crashes. As trends in the on-road fleet were being examined, all crashes (not just those involving pedestrians) were analysed.

Analysis

The main outcome measure used in this study is the risk of death or serious injury (hospitalisation) to the pedestrian given that some injury was sustained in a crash. In practice, pedestrians are almost always injured when hit by a vehicle in reported crashes, so including uninjured pedestrians in the analysis would have added little value to the analysis. To estimate the role of vehicle, pedestrian and driver factors in pedestrian injury severity, a logistic model was fitted with a response variable defined as 1 if the pedestrian was killed or hospitalised and 0 for injuries of lower severity.

Logistic regression was carried out using Proc Logistic from the SAS statistical package (SAS Institute Inc, 2012), employing maximum likelihood estimation. The explanatory variables available to be used to model pedestrian aggressivity are listed in Table 1. These were available for all jurisdictions and were expected from prior research to be associated with the injury outcome. The final three terms (State, year of crash, and the interaction between these) were designed to capture differences in the reporting of injury severity for different jurisdictions and changes in road safety levels across time.

Results

Estimates of pedestrian injury severity ratings

The logistic regression model for estimating changes in pedestrian injury severity by vehicle year of manufacture was of the following general form (with the levels of the main factors estimated shown in Table 2):

$$\text{Logit}(\text{Probability}(\text{Fatal or serious injury given some level of injury})) = \text{year-of-manufacture age(driver)} \\ \text{sex(driver)} \text{age(pedestrian)} \text{sex(pedestrian)} \text{speed-limit jurisdiction} \text{year-of-crash jurisdiction} \times \text{year-of-crash} \quad (1)$$

Table 2 shows the estimated odds ratios derived from this model. Statistically significant terms in the model have 95% confidence intervals that do not overlap 1. The comparison level for each factor is also shown. For example, the odds of a pedestrian fatal or serious injury when hit by a SUV was estimated to be around 20% higher than for a car (odds ratio point estimate of 1.2), although this was not statistically significant. Although not shown in this table, the model was run again but with a single term representing either a SUVs or commercial vehicles, to measure an average for this group of vehicles, as studied by Desapriya et al. (2010). The estimated odds of pedestrian fatal or serious injury when hit by either a SUV or commercial vehicle compared to a car (with all other terms in the model remaining the same) was 1.3 (95% CI 1.1-1.5).

Figure 1 shows the aggressivity to pedestrians of individual vehicle market groups by year of manufacture, represented as grouped years of manufacture to smooth some of the variation in the estimates. Nevertheless, there are often quite large confidence intervals (not shown, to avoid clutter),

Table 2. Adjusted odds ratio estimates with 95% confidence intervals for model predicting a fatal or serious injury given that the pedestrian was injured

Effect	Point Estimate	95% Wald Confidence Limits	
Vehicle type SUV vs car	1.2	0.9	1.4
Vehicle type commercial vs car	1.5	1.2	1.9
Additional decade since manufacture	0.8	0.7	0.9
Speed limit 55+ vs <55	1.6	1.4	1.8
Driver age under 26 vs 60 plus	1.4	1.1	1.8
Driver age 26-59 vs 60 plus	1.0	0.9	1.2
Driver sex F vs M	0.8	0.7	0.9
Pedestrian sex F vs M	0.8	0.7	0.9
Pedestrian age 0 - 9 vs 26-59	1.2	0.8	1.6
Pedestrian age 10-25 vs 26-59	1.0	0.9	1.2
Pedestrian age 60 plus vs 26-59	1.8	1.5	2.1

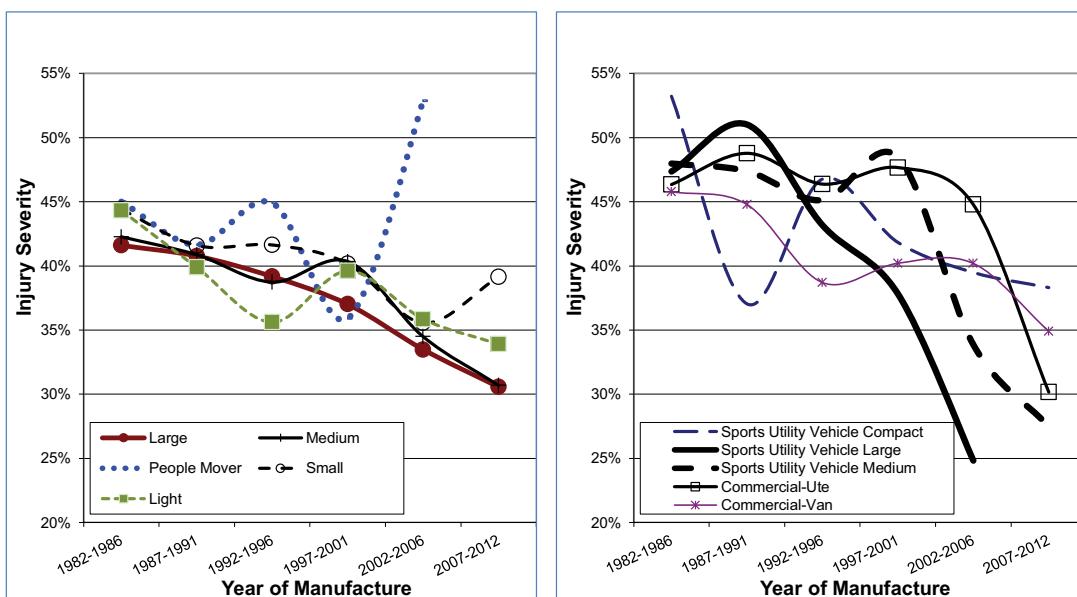


Figure 1. Estimated injury severity risks by vehicle market group for year of manufacture ranges, estimated from combined New Zealand and Australian data. Cars and people movers on LHS; SUVs and commercial vehicles on RHS

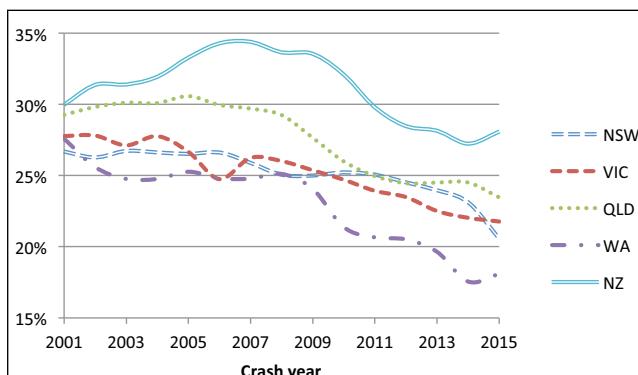


Figure 2. Percent of crashes that involved a driver age 25 or under, by crash year and jurisdiction

consistent with substantial fluctuation of the point estimates derived from relatively small sample sizes for some market groups. The more numerous market groups, such as the regular passenger car market groups (large, medium, small and light) show distinct downwards trends, whereas some of the other market groups display considerable fluctuation without clear trends (such as compact SUVs and people movers). It is the average of these trends that is captured by the term in Table 2 for “Additional decade since manufacture”.

Likely pedestrian fatal and serious injury effects from trends in driver and vehicle fleet composition

Figure 2 shows the proportion of reported crashes that involved a driver age 25 or under, by crash year and jurisdiction. In all the Australian States shown there has

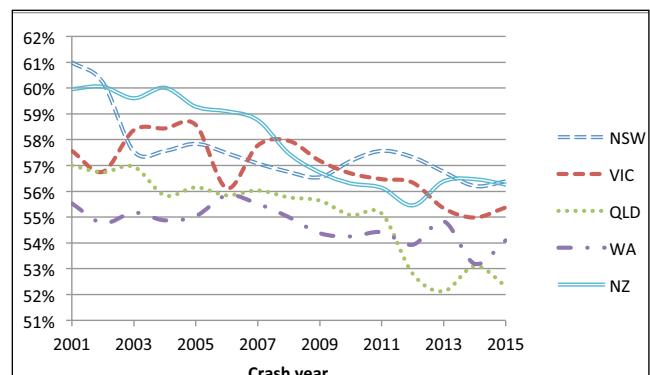


Figure 3. Percent of crashes that involved a male driver, by crash year and jurisdiction

been a reduction in the proportion of young drivers who were crash involved from 2001 to 2015. In New Zealand, there has been an overall reduction as well, despite an initial increase from 2001 to 2007.

Figure 3 shows the proportion of crashes that involved a male driver, by crash year and jurisdiction. This shows a similarly stronger trend for all jurisdictions studied. Of course, a graph of female driver involvement would show correspondingly increasing trends.

Table 3 shows total numbers of crash-involved vehicles and drivers, the proportion of these drivers who were male or age 25 or under, the average year of manufacture of the vehicle and the proportion that were SUVs and light commercial vehicles (known as Light Trucks and Vans, or LTVs, in the US) using combined data from NSW, VIC,

Table 3. Combined data from NSW, VIC, QLD, WA and NZ for crash-involved vehicles and drivers by year of crash

Year of crash	n vehicles	Driver Under 26	Male driver	Mean year of manufacture	Proportion SUVs and light commercials
2001	188,075	28%	59%	1992.8	14%
2002	195,574	28%	58%	1993.4	14%
2003	193,186	28%	57%	1994.2	15%
2004	194,973	28%	57%	1995.1	19%
2005	188,894	28%	57%	1996.2	20%
2006	188,617	28%	57%	1997.1	21%
2007	192,004	27%	57%	1998.1	22%
2008	185,965	27%	56%	1999.1	23%
2009	179,863	26%	56%	2000.0	24%
2010	163,652	25%	56%	2000.9	25%
2011	163,107	25%	56%	2001.7	26%
2012	169,703	24%	56%	2002.7	28%
2013	163,986	23%	56%	2003.6	29%
2014	158,063	22%	55%	2004.6	30%
2015	122,035	21%	55%	2004.9	31%

Table 4. Estimated relative odds of pedestrian fatal and serious injury arising from changes in Australasian fleets and driver characteristics from 2001 to 2015: contribution of each aspect individually and overall effect

Period	Driver Under 26	Male driver	Mean year of manufacture	Proportion SUVs and light commercials	Overall
2001-2015	0.98	0.99	0.76	1.04	0.77

QLD, WA and NZ. These aspects are important predictors of pedestrian fatal or serious injury according to the odds ratios estimated in Table 2. By applying estimated odds ratios from Table 2 to the changes in fleet composition and driver characteristics shown in Table 3, it is possible to estimate how pedestrian injury severity may have changed over time in response to these changes in the fleet and drivers, as shown in Table 4. Even though the increased proportion of SUVs and light commercial vehicles in the fleet was estimated to have increased pedestrian injury severity slightly (a 4% increase in the odds of fatal or serious injury), this is counterbalanced by the other factors, most notably more recent year of manufacture, which reduced fatal and serious injury odds by an estimated 24% on average, controlling for the other factors in the model represented by equation (1).

Discussion

This paper has looked at the way that different contributing factors to the severity level of pedestrian injury associated with changes in the vehicle fleets and characteristics of drivers in New Zealand and Australia. Pedestrian injury severity ratings were estimated as the probability of fatal or serious injury to the pedestrian given that a pedestrian injury occurred. Younger drivers (aged 25 and under) and male drivers were associated with higher severity pedestrian injury. Collisions with commercial vehicles (vans and utility vehicles) and SUVs were associated with higher odds of fatal and serious pedestrian injury than collisions with cars, which is likely to be related to their frontal structure geometry and stiffness. There was a trend towards better injury outcomes when the vehicle had a more recent year of manufacture, consistent with – but not necessarily attributable to – changes in vehicle design and manufacture. Trends over the past 15 years were also assessed using crash data from New Zealand and five Australian States. Applying the results of the regression conducted, these trends are likely to have yielded an approximate reduction of 23% in the odds of a pedestrian fatal or serious injury. All other factors being equal, increasing proportions of SUVs and commercial vehicles in these fleets will have increased pedestrian injury severity risks, but only by a small proportion. Estimates from this study suggest the main effect on pedestrian injury severity over the past 15 years has been a reduction in injury severity associated with gradually improving pedestrian outcomes with more recent year of manufacture of the colliding vehicle.

Desapriya et al. (2010) in a meta-analysis of studies comparing pedestrian injury outcomes in collisions with LTVs (light trucks and vans - equivalent to SUVs and commercial vehicles in our study) found an odds ratio for fatal injury of 1.54 (95% CI 1.15–1.93). If the risk of

hospitalised pedestrian injury is also increased in collisions with these vehicles, as is indicated by this study, then our finding of odds of 1.3 (95% CI 1.1-1.5) for fatal or serious injury is generally consistent with their estimate. There was insufficient power in our study to produce an estimate for fatal injury only. In the United States, 44% of pedestrians injured in crashes with vehicles are struck by LTVs (National Highway Traffic Safety Administration, 2018). From 2010 to 2012, the equivalent percentage in New South Wales, Queensland, South Australia and Victoria was 23%, only a little more than half the US figure. Although SUVs and light commercial vehicles are a concern in pedestrian injury in Australasia, there is clearly more cause for concern in the US. The current study indicates that increases in the proportions of these vehicles in Australasian fleets in recent years has had only a minor influence on pedestrian injury severity.

Based on the modelling of injury severity as a function of vehicle, driver and pedestrian characteristics, along with speed limit and jurisdiction, a reduction in pedestrian injury severity of around 23% was inferred over the past 15 years, all other factors being equal. It would have been useful to have looked at actual injury severity for pedestrians in crashes over this period to see whether this estimate derived from modelling is borne out. It is a limitation of the crash data available for the current study that injury severity is not consistently recorded over time, which hampers any attempts at consistent time series comparing severity levels. It is further a limitation of the current study that impact speeds could not be accommodated in the analysis. As with any cross-sectional study, there is the potential for some confounding. For example, if more recently manufactured vehicles were consistently driven at higher or lower speeds, this could confound the association between year or manufacture and pedestrian injury severity examined here.

The statistically significantly increased odds of pedestrian fatal or serious injury when the driver was young or male may be a consequence of higher speeds. As noted in the Introduction, crashes involving young drivers have been found to be more likely to have excessive speed as a factor, and more so for young males (McGwin & Brown, 1999). A recent Australian study found that surveyed male drivers were more commonly speeding than females according to self-report (Stephens, Nieuwsteeg, Page-Smith, & Fitzharris, 2017). Young drivers also lack the ability to recognise potential crash circumstances, limiting their options when averting a collision (Konstantopoulos, Chapman, & Crundall, 2010).

The estimated improvement in pedestrian injury outcomes when impacted by vehicles of more recent year of

manufacture found in the current study could be attributed to several factors. As noted in Background section, there are currently no Australian vehicle safety regulations specifically aimed to minimise the risk of injury to unprotected road users, despite the inclusion of pedestrian protection criteria in the New Car Assessment Programs of Australia, Europe and Japan. ANCAP results have shown important improvements in pedestrian protection ratings since 2003 (Paine et al., 2016), and these ratings have been shown to be correlated with real-world pedestrian injury outcomes, although only in lower speed limit areas (Strandroth, Rizzi, Sternlund, Lie, & Tingvall, 2011). It is also likely that pedestrian protection performance standards implemented in Europe and Japan have impacted on the Australian fleet via large numbers of vehicles from these markets sold in Australia.

Consultation with vehicle manufacturers was outside the scope of the current study, so it is unknown whether improved pedestrian outcomes have arisen from deliberate design choices aimed at pedestrian protection (perhaps in response to the new car assessment protocols or Japanese and European standards) or incidental changes related to materials and manufacturing methods along with the styling of the vehicles – or a combination of these mechanisms. The fitment of bullbars, more commonly to SUVs and light commercial vehicles, is not consistently recorded in the crash data so any potentially detrimental safety effects of this feature could not be examined. Some confounding of results is possible because of this. For example, if bullbars were fitted less frequently to more recent model vehicles, it is likely that some consequent safety benefit for newer vehicles would be found as a result.

Some emerging vehicle technologies are aimed specifically at – or include functionality for – preventing or reducing the severity of pedestrian injury, but considerable safety benefit may arise from technologies designed to reduce collision risk more generally, particularly those that are effective in lower speed limit areas where pedestrian crashes are more common. For example, Intelligent Speed Adaptation (ISA) assists compliance with speed limits either by warning the driver or actively slowing the vehicle control systems. It has the potential to reduce the risk of a wide range of crashes, including vehicle-pedestrian crashes, but its uptake may be limited by lack of acceptability to drivers who may resent its capacity to restrict speeds (Cairney, Imberger, Walsh, & Styles, 2010). Enhanced Night Vision similarly has some potential for reducing crashes with pedestrians at night. Collision Warning Systems and active pedestrian detection systems also have considerable potential, but the safety benefits for pedestrians and other unprotected road users are yet to be established with real-world crash data.

An example of a general crash-reducing technology that is most effective at higher speeds is Electronic Stability Control (ESC), for which benefits do not appear to accrue for pedestrians according to a meta-analysis (Høye, 2011). This may be because vehicle loss of control/traction (the situation where ESC becomes active in maintaining control) plays a relatively minor role in pedestrian injuries, or occurs predominantly in areas where pedestrian exposure

is not high. Autonomous Emergency Braking (AEB) has demonstrated promising results for preventing vehicles colliding with other vehicles (Fildes et al., 2015) and cyclists (Ohlin, Strandroth, & Tingvall, 2017), but data for pedestrians impacted by AEB-equipped vehicles are still too scarce to support reliable estimation of safety benefits (Ohlin et al., 2017).

One technology applicable to a range of crash types that *has* been evaluated in terms of pedestrian safety is the Brake Assist System (BAS). This technology has been evaluated by Breuer et al. (2007) based on a study comparing crash involvement of vehicles fitted with BAS with a control group not fitted with BAC. They concluded that severe pedestrian accidents were reduced by 13% associated with the BAS technology, which is slightly higher than an estimate of 10% made by Page et al. (2005). Brake assistance systems are now standard on a wide range of recent model vehicles and since 2013, ANCAP has only awarded five-star ratings for vehicles that performed sufficiently well in the crash tests *and* were equipped with BAS (ANCAP, 2018).

Conclusions

In this analysis of pedestrian injury outcomes in Australia and New Zealand, an improvement in pedestrian injury severity when impacted by vehicles with more recent year of manufacture was found. Other influences on pedestrian injury severity modelled, including an increasing prevalence of SUVs and commercial vehicles in the fleets, were estimated to have a relatively modest effect in recent years compared to this year of manufacture effect. It is probable that a combination of the pedestrian protection performance standards implemented in Europe and Japan, and vulnerable road user protection testing by New Car Assessment Programmes in Australia and internationally have benefitted the safety of the Australasian fleet.

Acknowledgements

This study was funded by the Vehicle Safety Research Group, a collaboration between Australian and New Zealand motoring clubs and government road safety agencies.

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A Systematic Review of Bicycle Helmet Laws Enacted Worldwide

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Key Findings

- Twenty-eight countries around the world have some form of bicycle helmet legislation;
- Current laws vary by maximum applicable age, the presence and amount of fines;
- All-ages helmet laws exist in nine countries, half of Canadian provinces, some US cities, urban travel in Chile and Slovakia, and interurban travel in Israel and Spain;
- There have been 273 laws enacted worldwide with only two being fully repealed

Abstract

A systematic review was undertaken to summarise bicycle helmet laws (BHL) enacted around the world, when they were introduced, available information regarding enforcement fines and whether they were later repealed. Jurisdictions with some form of BHL were identified using several sources including European Commission, Bicycle Helmet Safety Institute, government websites, and news articles. Wikipedia and advocacy group websites were also searched, but material was included only if verified from other sources. Road safety organisations in countries with existing BHL were also contacted. Information regarding date BHL was introduced, age of riders required to wear a helmet, what fines apply, and where and when BHL was modified or repealed, were gathered. There are currently 28 countries in total that have a helmet bicycle law. When the data is broken down in terms of countries, states, and cities, there have been at least 273 bicycle helmet laws enacted all over the world. Nine countries have bicycle helmet laws that apply to all ages as well as half of Canadian provinces, some US cities, urban travel in Chile and Slovakia, and interurban travel in Israel and Spain. To date, seventeen jurisdictions have modified their laws and only two laws have been fully repealed (Mexico City and Bosnia and Herzegovina). Although often presented as unique to cycling in Australia or New Zealand, bicycle helmet legislation has been enacted in many locations around the world. These laws are also robust with less than 1% of these laws (two instances) being fully repealed.

Keywords

Bicycle; helmet legislation; transport policy; cycling safety; systematic review

Introduction

There is no current, comprehensive list of bicycle helmet laws that exist around the world. Bicycle helmet legislation is an often-debated topic and these discussions should be informed by factual information. According to the Bicycle Helmet Safety Institute (2017), the U.S. state of California was the first place to introduce bicycle helmet legislation for passengers under 5 years of age in 1987, followed by the states of New York and Massachusetts in 1989 and 1990 respectively. In July 1990, the Australian state of Victoria became the first jurisdiction to introduce BHL for riders of all ages (Carr et al, 1995). The remaining Australian states and territories introduced similar legislation by 1992 (Australian Transport Safety Bureau, 2006).

Opponents of BHL often claim that only two countries (Australia and New Zealand) have bicycle helmet legislation (Rissel & Wen, 2011; Turner, 2012; Guy, 2015; Greaves, 2016), which is then used to argue for the repeal of such

legislation in Australia and to argue against the introduction of BHL in other countries. This is despite numerous research articles that have assessed the impact of BHL in other countries (Karkhaneh et al, 2013; Dennis et al, 2010; Bonander et al, 2014; Kett et al, 2016; Bauer et al, 2016). Although it is clear multiple jurisdictions have introduced BHL and despite the ongoing arguments for and against the effectiveness of BHL, there has been no systematic review to identify or summarise these laws. A summary of all bicycle helmet laws will greatly improve identifying relevant data which in turn will improve our knowledge of the potential effects of BHL.

This study aims to summarise bicycle helmet laws enacted worldwide. The data collected includes date of legislation, the maximum age the law applies, whether the law is enforced via fines or not, and whether the law was later modified or repealed.

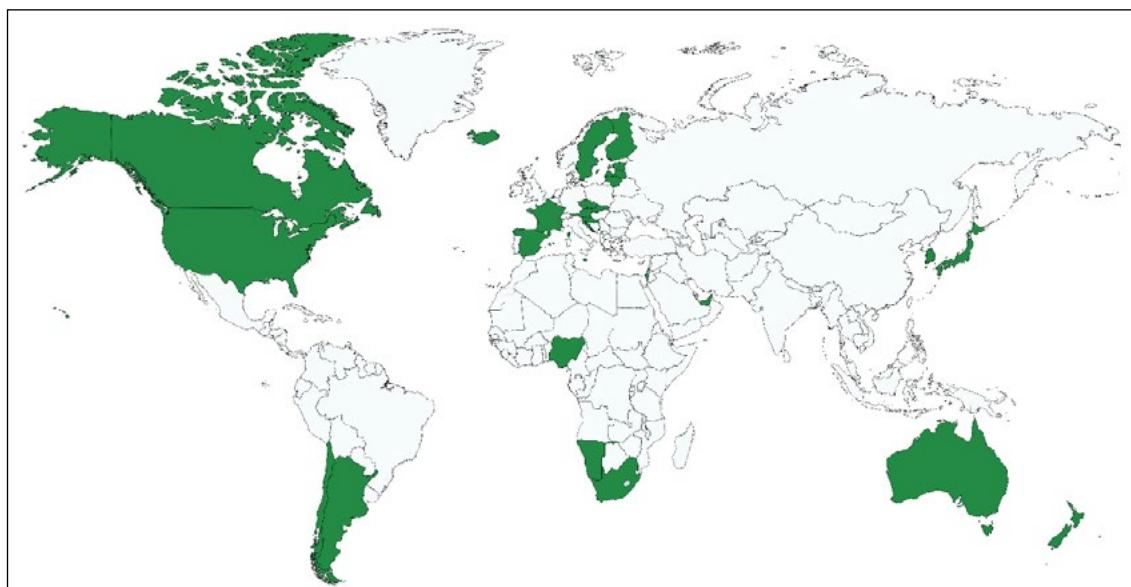


Figure 1. Map of Jurisdictions with Bicycle Helmet Legislation (*Canada and the United States do not have legislation for all provinces or states)

Methods

A Google desktop search was conducted in January 2017 to identify jurisdictions with BHL. Several sources were identified including reports from the European Commission (2015,2016), the Bicycle Helmet Safety Institute (2017), the International Transport Forum (2017), government websites, journal articles, technical reports, dissertations, and news articles.

Information regarding BHL effective date, age of enforcement, and fines, were gathered using the aforementioned sources, searching government websites, and contacting road safety organisations in countries with existing BHL. Wikipedia and websites sponsored by advocacy groups such as the Bicycle Helmet Research Foundation were also searched for relevant data; however, information was included only when verified by another source. Non-English sources were translated to English using Google Translate.

Results

Our search identified 28 countries around the world with some form of bicycle helmet legislation (see Figure 1). This includes legislation adopted in Argentina, Australia, Austria, parts of Canada, Chile, Croatia, Czech Republic, Estonia, Finland, France, Iceland, Israel, Japan, Jersey, Latvia, Lithuania, Malta, Namibia, New Zealand, Nigeria, Slovakia, Slovenia, South Africa, South Korea, Spain, Sweden, United Arab Emirates and parts of the United States. These laws differ in terms of enforcement and many apply only to children below a certain age. Nine countries have bicycle helmet laws that apply to all ages (Argentina, Australia, Finland, Malta, Namibia, New Zealand, Nigeria, South Africa, and United Arab Emirates). Additionally, five out of ten Canadian provinces and some US cities have all-ages

BHL, while all cyclists must wear helmets while travelling in urban areas in Chile and Slovakia, and between urban areas in Israel and Spain.

In Australia, Canada and the United States, road rules are often created at state, provincial, territorial or city levels. Therefore, these countries are discussed separately.

Australia

The state of Victoria was the first jurisdiction in the world to introduce bicycle helmet legislation for bicycle riders with effect from July 1990 for all ages and in all areas (Cameron et al, 1994). The remaining Australian states and territories followed with similar legislation by July 1992 (see Table 1).

New South Wales enacted a law for adults (16+ years of age, 1 January 1991) which was modified six months later (1 July 1991) to apply to all ages (Smith & Milthorpe, 1993). The Northern Territory (NT) first introduced legislation for adults (17+ years of age) on January 1992 and all ages by July 1992 (van Zyl, 1993). The NT law was further modified from 31 March 1994 to no longer apply to cyclists over the age of 17 who ride along footpaths or on cycle paths. Bicycle helmet legislation in the states of Queensland (July 1991) and Western Australia (January 1992) was initially introduced without enforcement, then with enforcement from January 1993 for Queensland and in July 1992 for Western Australia (King & Fraine, 1995; Healy & Maisey, 1992).

Note that although fines were not issued for the first six months in Western Australia, the police issued over 3,000 cautions during this time (Healy & Maisey, 1992), and fines of \$25 could be withdrawn during the first six months of enforcement if the cyclist provided proof of a helmet purchase within 14 days of being fined.

Table 1. Bicycle helmet legislation, Australia

	Effective date	Current fine (AUD)	Maximum age
Australian Capital Territory	Jul 1992	\$118	All
New South Wales	Jan 1991/Jul 1991	\$330	All
Northern Territory	Jan 1992/Jul 1992/Mar 1994	\$25	All
Queensland	Jul 1991	\$121	All
South Australia	Jul 1991	\$153	All
Tasmania	Jan 1991	\$260	All
Victoria	Jul 1990	\$194	All
Western Australia	Jan 1992	\$50	All

Canada

Eight out of ten Canadian provinces have some form of bicycle helmet legislation (Dennis et al, 2010; Bicycle Helmet Safety Institute, 2017). Ontario was the first province to enact BHL in October 1995, followed by seven other provinces by 2015 (see Table 2). The all-ages helmet law in Newfoundland and Labrador is applied to all cyclists riding on the province's roadways. A provincial map of Canadian helmet laws is given in Figure 2.

Quebec and Saskatchewan do not have bicycle helmet legislation although Yorkton, Saskatchewan has its own bicycle helmet bylaw and there are some municipal bylaws in Québec. None of the three territories of Canada

(Northwest Territories (NWT), Nunavut and Yukon) has a bicycle helmet law. However, the town of Inuvik, NWT, and the city of Whitehorse, Yukon, have enacted all-ages helmet bylaws.

Canada's current population is around 37 million with Quebec at 8.4 million (23%), Saskatchewan at 1.2 million (3%) and the three territories of NWT, Nunavut and Yukon totalling around 0.12 million (0.3%) (Statistics Canada, 2018). This means that around 73.7% (27.2 million) of Canada's population is subject to some form of BHL where 20% (7.2 million) is an all ages BHL. For provinces with child only laws (Alberta, British Columbia, and Manitoba), the population 14 years and younger was an estimated 3.2 million on 1 July 2017 (Statistics Canada, 2017).

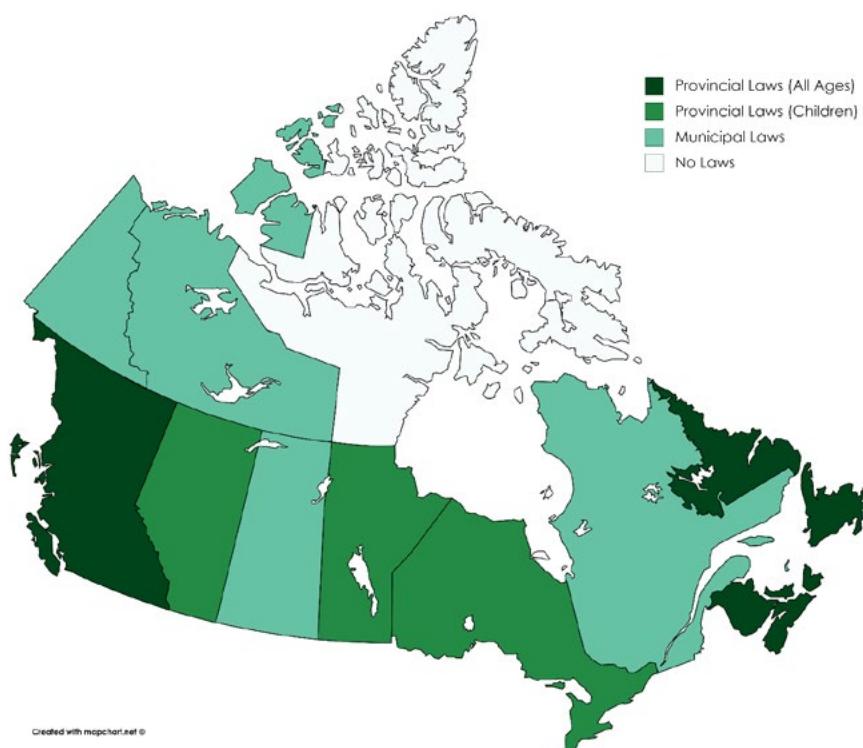
**Figure 2. Map of Canadian Provinces with Bicycle Helmet Legislation**

Table 2. Bicycle helmet legislation, Canada

	Effective date	Current fine		Maximum age
		(CAD)	(AUD) ^c	
Alberta	May 2002	\$69	\$70	17
British Columbia	Sep 1996	\$100	\$102	All
Manitoba	May 2013	Up to \$50 ^a	Up to \$51	17
New Brunswick	Dec 1995	\$21	\$21	All
Newfoundland & Labrador	Apr 2015	\$25-\$180	\$26-\$184	All
Nova Scotia ^b	Jul 1997	\$128	\$131	All
Ontario	Oct 1995	\$60	\$61	17
Prince Edward Island	Jul 2003	\$100	\$102	All

^a Fine can be dismissed if the cyclist takes the Manitoba Bike Helmet Safety Course.

^b Fine is replaced with a 2-hour education program delivered by police, health professionals and injury survivors

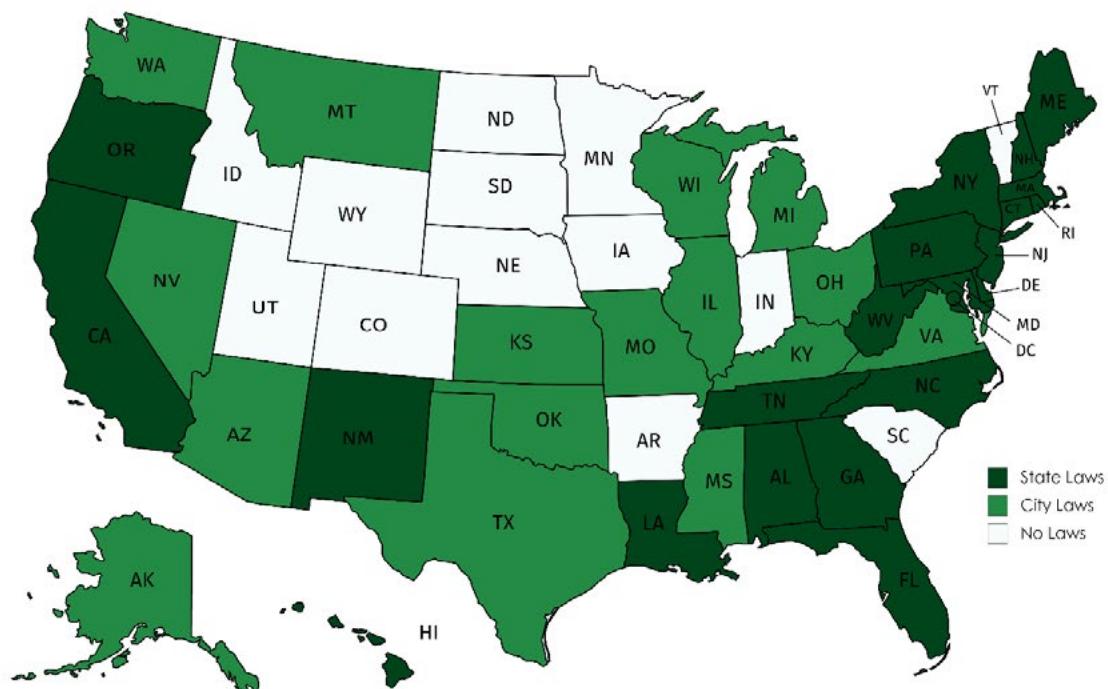
^c Conversion rate based on 10th April 2018 exchange rate rounded to nearest dollar value

United States

The state of California was the first jurisdiction in the world to introduce bicycle helmet legislation, although it applied only to passengers under 5 years of age. By 2007, an additional 36 states and the District of Columbia (DC) had enacted some form of bicycle helmet legislation (see Table 3). Sixteen states have only city-wide laws and 13 other states do not follow any form of bicycle helmet legislation

including Arkansas, Colorado, Idaho, Indiana, Iowa, Minnesota, Nebraska, North Dakota, South Carolina, South Dakota, Utah, Vermont, and Wyoming. In total, 21 states, the District of Columbia, and 203 cities, have some form of bicycle helmet legislation. Note that all state-level helmet laws in the US relate to children.

Further information related to the laws for each state/city of the United States can be found on the Bicycle Helmet

**Figure 3. Map of US States with Bicycle Helmet Legislation**

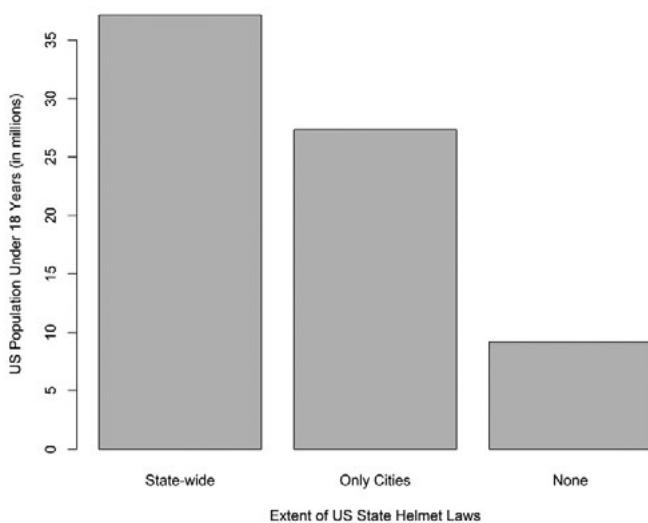


Figure 4. US population under 18 years of age by helmet law categories (source: US Census Bureau, 2017)

Safety Institute website (<http://www.bhsi.org/>). A state map of US helmet laws is given in Figure 3, and Figure 4 summarises the US population under 18 years of age by states categorised as having state-wide helmet laws, city only laws, or no laws.

In 1994, Tennessee passed a law requiring the use of helmets for cyclists under the age of 16. There was a move to repeal the law, but it was reconfirmed in 2000. Following a referendum in the City of Seymour, Connecticut, the all-ages helmet law was repealed in September 1998, two months after its introduction in July 1998. However, helmet legislation still applies to children up to 16 years of age due to a state-wide law in Connecticut. In Dallas, Texas, all-ages bicycle helmet legislation was enacted in 1996 and was relaxed in 2014, which then applied to children under 18 years. In Snohomish, Washington, an all-ages law was repealed in 2002; however, an existing law still applies to skate parks.

The original 1987 California helmet law was later modified in 1994 to apply to child riders under 18 years of age. Similarly, the Massachusetts' 1990 law was modified in 1994 and 2004, which applied to children under 12 and 17, respectively. Bicycle helmet legislation was also modified in the state of New York. The 1989 law was modified in 1994 to apply to children under 14 years. Pennsylvania introduced legislation in 1991 for children under 5 years, which was modified in 1995 to apply to children under 12 years. Rhode Island also modified the applicable age in their 1996 law for children under 9 years to children under 16 years in 1998.

Other Jurisdictions

Apart from Australia, Canada, and United States, there are 25 countries with some form of bicycle helmet legislation (see Table 4). Among these countries, New Zealand (Povey et al, 1999) and France (Ministry of the Interior, 2016) were the first and the last to introduce legislation in 1994 and 2017, respectively.

Mexico City repealed their bicycle helmet law in February 2010, two years after its introduction in 2008. The repeal was motivated to support their shared bicycle rental program (Bicycle Helmet Safety Institute, 2017), although no evaluation of the repeal on cycling distances/trips travelled or any other measure of cycling exposure, cycling injury or road deaths could be found. Bosnia and Herzegovina introduced an all-ages bicycle helmet law in 2006 and was later repealed in March 2017. The repeal occurred after a six-year effort by the Centre for Environment campaign (Reid, 2017). There was an initial proposal in Finland to modify or repeal their helmet law; however, any potential changes in helmet legislation have been removed from discussions of their road traffic laws (Finnish Government, 2017 (b)). Malta is currently considering repealing their bicycle helmet law; however, new rules are currently being drafted and have not taken effect (Reljic, 2018).

In Argentina, children under 12 years of age are allowed to ride in parks without having to wear helmets. In Chile, helmet wearing is mandatory in urban areas for all ages, and not obligatory when riding in rural zones. Israel modified its all-ages law enacted in 2007. Since 2011, children under 18 years and all cyclists on interurban roads must wear a helmet when cycling. Czech Republic first introduced BHL for children under 16 years in 2001 which then changed in 2006 and applied to children under 18 years. In Slovakia, cyclists of all ages must wear a helmet except for cyclists older than 15 years when riding outside populated areas. Spain modified its all-ages law in 2014 where children under 16 years must wear a helmet regardless of the route and adults must wear a helmet when riding on interurban routes, except when travelling uphill, presumably because of heat effects and travelling uphill is slower.

There have been seventeen jurisdictions that have modified existing bicycle helmet laws, including three countries (Czech Republic, Israel, Spain), two Australian states (New South Wales, Northern Territory), six US states (California, Connecticut, Massachusetts, New York, Pennsylvania, Rhode Island), and six US cities (Austin TX, Seymour CT, Dallas TX, Snohomish WA, Southlake TX, St Louis County MO).

As summarised in the tables, the fines levied for violation of bicycle helmet legislation vary substantially among the jurisdictions. In all states of Australia, fines range from AUD25 to AUD330. In Canada, fines between CAD21 and CAD180 apply in all provinces with legislation. In the United States, fines apply in some states (between USD2 and USD100), but not all. In addition, fines apply in 12 out of the 23 other countries with some form of bicycle helmet legislation, with the highest rate in Spain (€200 which is equal to about AUD317 at the time this paper was written). The Australian state of New South Wales currently has the largest fine in the world (AUD330).

Table 3. Bicycle helmet legislation, United States

	State or city law ^a	Effective date	Current fine		Maximum age
			(USD)	(AUD) ^c	
Alabama	S	1995	\$50	\$65	15
Alaska	C (5)	-	-	-	-
Arizona	C (5)	-	-	-	-
California	S	1987/1994	up to \$25	Up to \$32	4/17
Connecticut	S	1993/1997	No fine	No fine	15
Delaware	S	1996	\$25-\$50 ^b	\$32-\$65 ^b	17
District of Columbia	S	2000	\$25	\$32	15
Florida	S	1997	\$17	\$22	15
Georgia	S	1993	No fine	No fine	15
Hawaii	S	2001	\$25	\$32	15
Illinois	C (6)	-	-	-	-
Kansas	C (1)	-	-	-	-
Kentucky	C (1)	-	-	-	-
Louisiana	S	2002	No fine	No fine	11
Maine	S	1999	\$25	\$32	15
Maryland	S	1995	No fine	No fine	15
Massachusetts	S	1990/1994/2004	No fine	No fine	4/11/16
Michigan	C (3)	-	-	-	-
Mississippi	C (4)	-	-	-	-
Missouri	C (39)	-	-	-	-
Montana	C (1)	-	-	-	-
Nevada	C (2)	-	-	-	-
New Hampshire	S	2006	No fine	No fine	15
New Jersey	S	1992	up to \$100	up to \$129	16
New Mexico	S	2007	up to \$10 ^c	Up to \$13 ^c	17
New York	S	1989/1994	\$50	\$65	4/13
North Carolina	S	2001	\$10c	\$13c	17
Ohio	C (24)	-	-	-	-
Oklahoma	C (2)	-	-	-	-
Oregon	S	1994	\$25 ^c	\$32 ^c	15
Pennsylvania	S	1991/1995	up to \$25 ^c	up to \$32 ^c	4/11
Rhode Island	S	1996/1998	No fine	No fine	8/15
Tennessee	S	1994/2000	\$2	\$3	15
Texas	C (9)	-	-	-	-
Virginia	C (31)	-	-	-	-
Washington	C (34)	-	-	-	-
West Virginia	S	1996	\$10 ^d	\$13 ^d	14
Wisconsin	C (1)	-	-	-	-

^a S = state law exists. C = no state law, but there is/are city law/s. Number of cities with some form of legislation in parentheses.

^b Cyclists will be fined \$25 for the first offense and \$50 for each subsequent offense.

^c In New Mexico, North Carolina, Oregon, and Pennsylvania, fine for not wearing a helmet waived if the cyclist provides a proof of helmet purchase.

^d Parents will be fined \$10 or be required to perform two hours in community service related to a child injury prevention program.

^e Conversion rate based on 10th April 2018 exchange rate rounded to nearest dollar value

Table 4. Bicycle helmet legislation, All Jurisdictions

	Effective date	Current fine^a	Maximum age
Argentina	2004	No fine	All
Australia	July 1990-July 1992	A\$25 – A\$330	All
Austria	Jun 2011	*	12
Canada	Oct 1995-Apr 2015	C\$21 - C\$180 (A\$21 - A\$184)	All/17
Chile	2009	UTM 0.5 - 1	
(A\$29 - A\$58)	All		
Czech Republic	2001/2006	Fines apply	15/18
Croatia	2008	HRK 300 (A\$64)	16
Estonia	Jul 2011	€15-20 (A\$24-A\$32)	16
Finland	Jan 2003	No fine	All
France	Mar 2017	€135 (A\$215)	12
Iceland	Sep 1999	No fine	15
Israel	Jul 2007/Aug 2011	No fine	All/18
Japan	2008	No fine	13
Jersey	Oct 2014	Fines apply (unknown)	12
Latvia	Oct 2014	*	12
Lithuania	*	*	18
Malta	Apr 2004	*	All
Namibia	*	NAD 100 (A\$11)	All
New Zealand	Jan 1994	NZD 55 (A\$52)	All
Nigeria	At least since 2012	N2000 (A\$7)	All
Slovakia	*	Fines apply	All
Slovenia	2000	€120 (A\$191)	15
South Africa	Oct 2004	No fine	All
South Korea	2006	*	13
Spain	2004/2014	€200 (A\$319)	All/15
Sweden	Jan 2005	€55 ^b (A\$88)	15
United Arab Emirates	2010	AED 500 (A\$176)	All
United States	1987-2007	US\$0 - US\$100 (A\$0 - A\$129)	

^a Conversion rate based on 10th April 2018 exchange rate rounded to nearest dollar value

^b There is no penalty for children. However, parents cycling with unhelmeted children are liable to a fine of €55 Euro.

* Information was not found

ALL is law applies to ‘All Ages’

Discussion

Since the introduction of the first bicycle helmet law in 1987, there have been at least 273 bicycle helmet laws enacted all over the world (encompassing countries, states, provinces, territories, and cities). Two of these laws have been fully repealed including Mexico City (2010) and Bosnia and Herzegovina (2017). To the best of our knowledge, there have been no assessments regarding the impact of these repealed laws on either cycling distances/trips travelled, injury or road deaths.

The motivation for introducing BHL is to increase bicycle helmet wearing and, consequently, decrease bicycle related

head injury and fatalities as well as any associated societal costs. Although it has often been presented as being limited to Australia and New Zealand, BHL exists in many parts of the world with varying rules, enforcement levels, and affected ages.

BHL has been enacted in about half of the OECD, IRTAD and EU countries around the world irrespective of the measure. This includes nineteen of thirty-five members of the Organisation for Economic Co-operation and Development (OECD, 2018), nineteen of the forty members of the International Traffic Safety Data and Analysis Group (IRTAD) (International Transport Forum, 2018), and thirteen of the twenty-eight members of the European Union (EU).

Bicycle helmet laws often differ across jurisdictions due to discussions and debates prior to and following enactment. The Northern Territory, for example, discussed three options based on the cyclist's age – (1) all ages, (2) young people first and then adults, and (3) adults first and then young people (van Zyl, 1993). The NT government decided on the third option since adults comprised more than 70% of cycling injuries. Other jurisdictions have pushed for helmet legislation for children only since there is greater acceptance for younger age groups than adults (Hooper & Spicer, 2012; Biegler & Johnson, 2015; Swedish Government, 2004). In Finland, there have been discussions regarding the word *yleensä* mentioned in their helmet law. This word can be translated as both “usually” or “in general”, which limits the government’s ability to enforce the law and has led some to interpret the law as a recommendation. Helmet laws have previously been discussed for New York City which was opposed by then mayor Michael Bloomberg. There was speculation that Bloomberg was not opposed to the law itself but to the city councilman who proposed the bill (Bateman-House, 2014).

Helmet legislation has been introduced for electric bicycles (ebikes) as well. To our knowledge, this includes all of Australia, parts of Canada, New Zealand, Switzerland, and parts of the United States. The proportion of ebikes has been rising, especially among older cyclists (Fishman & Cherry, 2016).

There are several limitations to the current systematic review. First, jurisdictions often report laws only in their own language and an accurate translation to English may be difficult. Second, there was conflicting information identified for some jurisdictions, such as Argentina, which was not listed as having a bicycle helmet law by IRTAD (ITF, 2017). However, article 40 of their road rules (*Ley de transito, articulo 40*) and an Argentinian legal advice website (*Luchemos por la vida*, 2009) state cyclists are required to wear protective helmet when riding a bicycle. Similarly, some sources reported that Nigeria does not have BHL; however, Nigeria has been listed with all ages BHL by IRTAD (ITF, 2017) which was verified by their road rules (regulation 195 of the National Road Traffic Regulations).

Conclusions

It is often claimed Australia and New Zealand are the only countries with bicycle helmet legislation and this claim is sometimes qualified as they are the only countries with all-ages laws. In this search, 28 countries were identified in total that have bicycle helmet legislation with nine countries (Argentina, Australia, Finland, Malta, Namibia, New Zealand, Nigeria, South Africa, and United Arab Emirates) having all-ages BHL. All-ages helmet laws also exist in Canada, Chile, Israel, Slovakia, Spain and the US depending on location or whether the cyclist is travelling in an urban or interurban area.

When the data is broken down in terms of countries, states, provinces, territories, and cities, there have been at least 273 bicycle helmet laws enacted worldwide. Additionally, these laws have been reasonably robust over the past 30 years with only two jurisdictions having fully repealed their laws.

Acknowledgements

This study was funded by the Swedish Transport Administration (Trafikverket). The funders had no part in the design, data collection, or interpretation of the reported results.

The authors would like to thank Catharina Arvidsson (VTI), Michal Bil (Czech Transport Research Centre), Erin Berenbaum (Public Health Ontario), Carl Bonander (Karlstad University), David Cosgrove (Australian Bureau of Infrastructure, Transport and Regional Economics), Spiros Frangos (Bellevue Hospital Center, New York University), Lindsay Gaudet (University of Alberta), John Hurlbert (University of Calgary), Soames Job (Global Road Safety Solutions), Mohammad Karkhaneh (University of Alberta), Michael Koucky (Koucky & Partners AB), Pablo Lardelli-Claret (University of Granada), Carmen Meneses Falcón (Universidad Pontificia Comillas), Tom Petersen (Trafikanalys, Sweden), Igor Radun (University of Helsinki), Chika Sakashita (Global Road Safety Solutions), Katja Schleinitz (University of Technology Chemnitz), Robert J. Schneider (University of Wisconsin-Milwaukee), Jónína Snorradóttir (Icelandic Association for Search and Rescue), Helena Stigson (Folksam), Randy Swart (BHSI), and Naveen Wijemanne (ACT Justice and Community Safety) for providing valuable information for this report.

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Safe Roads for Cyclists: An Investigation of Australian and Dutch Approaches

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Key Findings

- Austroads cycling guidelines do not coincide with best practice principles
- Non-compliant cycling facilities in Melbourne impact safety and network continuity
- Connecting cycling infrastructure would increase cyclist safety and amenity

Abstract

In countries with high cycle mode share, separated infrastructure and low speeds are fundamental to creating a safe cycling environment. The Dutch approach to cycling design is an exemplar of best practice accredited with contributing to the success of high cycle mode share in The Netherlands. The aim of this study was to assess the Australian approach to bicycle infrastructure against the Dutch principles, and investigate conditions on the road. This pilot study used a mixed method approach and was conducted in two parts: 1) a desk-based comparison of the cycling-related road design guidelines in The Netherlands and Australia and, 2) case studies of two primary access routes to a major commuter destination in suburban Melbourne (Monash University). Key differences between the Australian and Dutch approaches were identified from the respective design guidelines for shared-priority local streets, mid-block sections on arterial roads, and at intersections. The Dutch approach requires physical separation between bicycles and cars in most cases, whereas Australian guidelines focus on the details of design rather than an overarching principle of separation. On road, the case study routes were only partially compliant with Australian guidelines with considerable gaps along the route. Potential changes to the Australian guidelines in relation to the Dutch approach and further research are presented.

Keywords

cycling, infrastructure guidelines, Australia, Dutch best practice, safety

Introduction

Globally cities are facing issues with mobility and vehicle congestion as increasing urbanisation impacts safe and efficient travel (Li and Faghri, 2014). Decades of prioritising road space to motor vehicles has led to ‘induced demand’, an economic theory which explains how increased supply leads to increased demand (i.e. more roads leads to more people driving; Næss et al, 2012). This has contributed to a range of negative unintended consequences (e.g. vehicle congestion, extended travel times, vehicle emissions etc). Internationally, cities are shifting their transport focus from the movement of motor vehicles, to the movement of people. Bicycle transport can provide an attractive means of moving people, particularly over short trips (up to 8km) or as a part of longer multi-modal trips. It enables more flexible use of the road, relieves traffic congestion, improves urban mobility, and can deliver public health benefits.

Benefits of cycling for transport are well-documented (Oja et al, 2011) however, Australia’s uptake of cycling as a transport mode is low when compared with northern European countries including The Netherlands, Denmark

and Germany (Pucher and Buehler, 2008; Pucher et al, 2011). The nation-wide proportion of commute trips made by bicycle remained stagnant between 2011 (1.2%) and 2016 (1.1%) (ABS 2017). A wide range of barriers are postulated to contribute to the low modal share of cycling, including perceived risk, trip distance, inconvenience and Australia’s historic affinity for the private motor vehicle. However, two key factors facilitating ridership in successful cycling countries is the provision of a connected network of separated cycling infrastructure (Pucher and Buehler 2008; Marques et al, 2015) and low speed limits (e.g. 30kph) (Wooldridge et al, 2016).

Internationally, there is evidence supporting the effectiveness of enhanced cycling infrastructure in generating increased ridership. New on-road separated bicycle lanes enhanced comfort for both cyclists and motorists in Portland, Oregon, USA (Monsere et al, 2012). In Seville, Spain, an overhaul of the city’s bicycle infrastructure between 2006 and 2011 led to significant benefits (Marques et al, 2015). In Australia, studies of specific, local treatments concur; Heesch et al.

(2016) reported accelerating growth of seasonally-adjusted monthly bicycle counts (88 to 178) following the opening of Brisbane's V1 Veloway. However, action is needed at a network level with a positive correlation reported between cycling levels and policy, program and infrastructure interventions, highlighting a comprehensive network to increase ridership compared with localised treatments (Buehler and Dill, 2016; Pucher et al, 2010).

In Australia, while local treatments continue to be implemented, connected, networked cycling infrastructure provisions are lacking. Current provisions along roads in midblock sections and at intersections present risk to cyclists and compromise comfort and convenience. Such deficiencies violate key principles supporting cycling participation (Pucher et al, 2011; Mulvaney et al, 2015; Stevenson et al, 2015). This is in part confounded by the governance structures that oversee infrastructure in Australia.

Strategic Context and Cycling Planning Authorities

All road infrastructure in Australia comes under the governance of the National Road Safety Strategy 2011–2020 (Australian Transport Council, 2016), modelled on the Safe System approach. This approach recognises that people will make mistakes when using the road, and that our bodies can only withstand a finite amount of force before suffering injury or death. The road transport system must aim to minimise crash occurrence and severity through four key pillars: safe roads, safe speeds, safe vehicles and safe people. Alongside the NRSS, the National Cycling Strategy 2011–2016 was overseen by the Australian Bicycle Council (ABC). Following a 2017 review, the ABC is to be re-formed as a Cycling and Walking in Australia/New Zealand (CWANZ) working group, with no immediate aim for a replacement strategy (ABC, 2017).

National road design guidelines are incorporated into the *Austroads Guides to Road Design* volumes, which aim to apply a Safe System approach to road design through Safe Roads. The *Cycling aspects of Austroads guides* document (Austroads, 2017) brings together cycling-specific components from all Austroads volumes and is the primary resource for practitioners designing bicycle infrastructure in Australia (VicRoads, 2017a; Bicycle Network, 2015). It is not well-explored, however, how this volume correlates with the overarching Safe System principles, or with international best practice.

State road authorities and municipalities produce additional standards for their jurisdictions. In Victoria, VicRoads publishes supplementary bicycle infrastructure guidelines in their Traffic Engineering Manual (VicRoads, 2016a; VicRoads, 2016b) and municipalities (local government) define objectives within their respective transport strategies. This multi-layered approach creates difficulties for infrastructure planners and designers when seeking an optimal design solution for a given project, especially when connecting a route across municipalities.

Dutch Design Approach

Internationally, the Dutch approach is recognised as best practice in cycling provision (Pucher and Buehler, 2008; Portland Bureau of Transportation, 2010). Cyclist fatality rates in the Netherlands the lowest in the world, estimated at 1.0 per 100 million kilometres cycled, compared to 1.1 in Denmark, 2.5 in the United Kingdom and 4.7 in the United States of America (Buehler and Pucher, 2017), hence the *Dutch Design manual for bicycle traffic* (CROW, 2007) was used as the best practice reference.

The Dutch design approach is underpinned by five requirements for cyclist amenity (CROW, 2007). These are repeated throughout the manual to inform all infrastructure design choices:

- Safety: bicycle infrastructure uses separation to protect vulnerable cyclists
- Cohesion: the network is connected and links key destinations

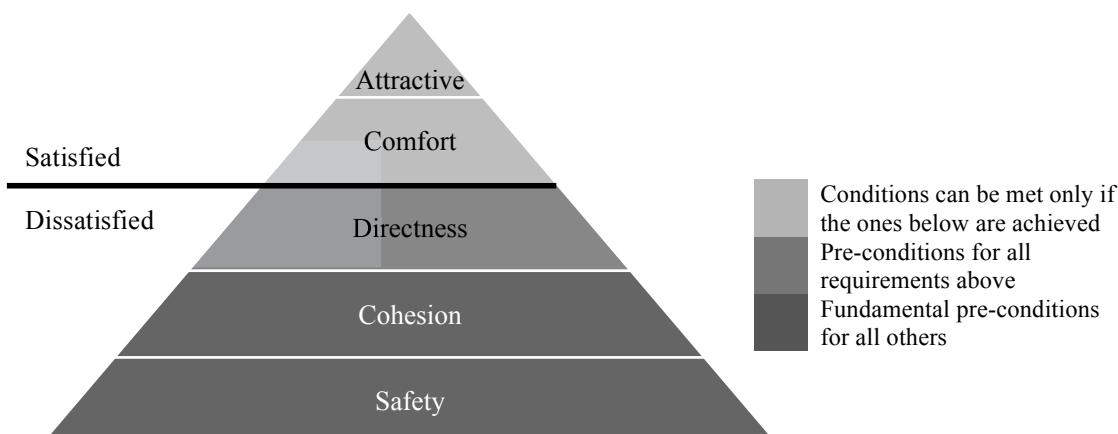


Figure 1. Dutch requirements for cycling amenity
(Adapted from: Scheltema, 2012)

- Directness: the network provides a route which is direct in both space and time
- Comfort: the network makes cycling less complex and require less exertion
- Attractiveness: network provisions address individual barriers to cycling

Scheltema (2012) used Maslow's hierarchy as a model to structure these principles as a hierarchy that requires each stage to be fulfilled before amenities are satisfactory for cycling (Figure 1). With safety, cohesion and directness the minimum requirements.

Study Aims

This study comprised two primary aims:

1. To assess how Australian design guidelines for cycling infrastructure compare with international best practice and the overarching Safe System principles, and
2. To identify areas for improvement in physical infrastructure to align with Australian guidelines and international best practice principles.

Methods

A mixed method approach was used, including:

1. A desk-based analysis to compare infrastructure guidelines, addressing aim 1, and
2. A case study component, utilising on-road naturalistic observations and subsequent infrastructure assessment, addressing aim 2.

Component 2) considered on-road infrastructure connecting to Monash University's Clayton Campus, a major destination in the bicycle network in the south-eastern suburbs of Melbourne. A 2016 online travel mode survey found that around 4% of students accessed the University by bicycle (Sift Research, 2017). On a weekday in March 2017, 465 cyclists were counted entering the University between 8am and 11am (Monash University, 2017).

Comparison of Cycling Infrastructure Guidelines

This component of the study sought to highlight the general areas in which cycling components of Australian cycling infrastructure design guidelines do and do not meet international best practice.

Comparison of infrastructure guidelines is made using two key sources:

Australian approach: *Cycling aspects of Austroads guides* document (Austroads, 2017)

Best practice approach: *Dutch Design manual for bicycle traffic* (CROW, 2007).

For brevity, only selected road types and bicycle infrastructure treatments were considered. Selection of road types was informed by the study locality (around Monash University) to compliment the case study component. Specific road types included in this component are: local streets (default urban speed limit, 50kph); access roads (50kph); arterial roads (60, 70, 80kph); and intersections between these road types.

Selected infrastructure types included mid-block treatments (exclusive bicycle lanes), intersection provisions (approach and departure bicycle lanes), and shared car/bicycle priority on local streets (LATM – Local Area Traffic Management techniques). These types were selected due to being prevalent in the study locality.

Infrastructure types not considered in this comparison include, but are not limited to; roundabouts, off-road shared paths, shared bicycle/bus lanes and grade-separated crossings.

On-Road Naturalistic Case Studies

The major cycling routes into the University were investigated. Ten key routes were selected using the Monash City Council *Walking and cycling map*, which is publicly available for cycle trip planning in the area. The routes vary in length from 1.7-3.3 km and are indicated on the locality map (Figure 2). Several alternative routes were excluded due to high traffic speeds (70-80kph) and a lack of cycling infrastructure provision.

An author (JD) collected naturalistic observations by undertaking a saddle survey – cycling each of the routes and recording front-facing video footage with a handlebar-mounted camera. The camera also recorded GPS data, hence capturing the rider's speed and precise location. Where a bicycle lane was provided, its width was measured during the survey. Following the survey the author recorded lived-experience notes, detailing the relevant comfort of cycling through each location.

Two of the selected routes were isolated for temporal-snapshot case study analysis. These lie on a Strategic Cycling Corridor (SCC) (VicRoads, 2017b), have been the subject of earlier work (Reid and Rose, 2013; Safe System Solutions, 2015; Safe System Solutions, 2017) and vary considerably in relation to speed, traffic volume and composition. This enabled current deficiencies and potential upgrades to be highlighted on distinctly different road types. Case Study routes are marked as solid lines on Figure 2.

Case study 1

This route is 2.1 km long with varied speed zones (50kph, 60kph) and varied road cross section along its length (4 lane divided arterial road, 2 lane undivided collector street). This route has key intersections with the Monash Freeway interchange and Ferntree Gully Road. Published AADT data (VicRoads, 2017c) was obtained for arterial roads traversed on this route. Inbound and outbound routes were assessed individually.

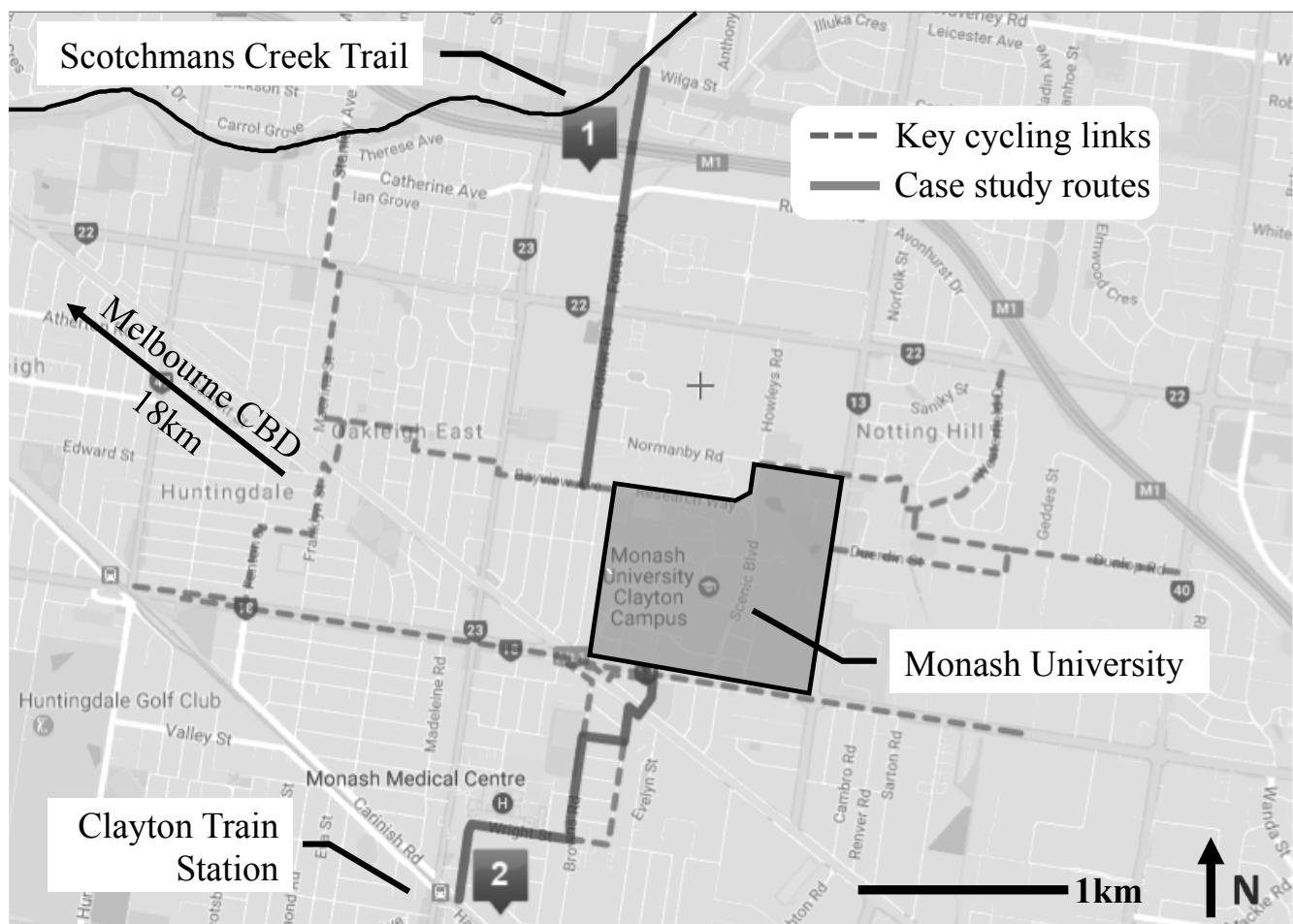


Figure 2. Locality map identifying case study routes and major destinations
(Source: Scribble Maps, 2017)

Case study 2

This route is 2.1km long and links Clayton train station with the University via local roads (50kph, 40kph). Key intersections include Princes Highway and Wellington Rd. AADT data was not available for the roads on this route, however traffic volumes are estimated to be considerably lower than Case Study 1.

Case study road segment classification

Both routes were classified into segments (in Figures 3 and 4) according to the current infrastructure types, then each segment coded by their compliance with Austroads:

- Boxed:** compliant with Austroads guidelines, although in some cases CROW recommended an alternate treatment.
- Dashed:** partially compliant with Austroads.
- Solid:** non-compliant with Austroads. Upgrade works required for compliance with Austroads and best practice guidelines.

Criterion used to assess road segments include: approximate traffic volume (where available), speed limit, road cross-sectional configuration, and presence or absence of adjacent car parking. Finally, segments were assessed against the CROW manual to identify the best practice infrastructure treatment for that location.

Results

Comparison of Australian and Dutch guidelines

A system level approach was used to identify the overarching Austroads principles for providing a safe and continuous bicycle network and assess these against the Dutch approach detailed in the CROW manual. Of the road types assessed, Austroads design guidelines for physical infrastructure were found to be consistent with the Dutch manual in several areas. Both documents recommend on-road bicycle lanes in similar situations, and both suggest off-road kerb-separated cycle tracks in other scenarios.

Network considerations

Austroads identifies the importance of a network in linking major destinations via desire lines but the topic is covered briefly. The five Dutch main requirements are reproduced with limited detail in the introductory chapter. Network connectivity is mentioned briefly in guidelines for mid-block and intersection treatments, but does not regulate design.

The CROW manual takes a movement and place approach and dedicates an entire chapter to network planning. It states that network significance should inform site-specific design in all cases and includes detailed network modelling techniques to advise policy and decision-making. The five main requirements are used to assess both specific designs and wider network characteristics.

Local streets

Local streets form significant links within bicycle networks due to their separation from high speed and high traffic routes. Both manuals recommend either wide lanes which allow motor vehicles to pass cyclists, or narrow lanes which force drivers to travel behind cyclists.

Austroads does not give detailed guidelines for local streets. Instead, it targets a 40kph speed limit and suggests LATM treatments to meet this goal while protecting cyclist amenity. It is important to note that in most local streets in Victoria, the current default speed limit is actually 50kph. Bicycle-friendly speed bumps are recommended and horizontal speed control measures are discouraged as they create a squeeze point for cyclists. Austroads does not account for unregulated kerbside parking.

CROW has similar goals for this road type, with a 30kph speed limit and shared priority between bicycles and cars. A parking lane or indented parking bays should be delineated if parking is allowed along greater than 20 percent of the road length. A critical reaction strip is recommended between the parking and traffic lanes, to prevent cyclists being hit by opening car doors.

Mid-block treatments on arterial roads

50kph roads: Austroads stipulates that separation of bicycle and motor vehicle traffic should occur when the design speed differential is greater than 20kph. However, no detail is given for provisions on 50kph roads. CROW considers a 50kph road as a major district access road, requiring bicycle lanes on roads with one traffic lane each way (2x1) and a separated “cycle track” on roads with two traffic lanes each way (2x2).

60kph roads: Exclusive bicycle lanes are generally recommended by Austroads on 60kph roads, including additional width allowance for a bike lane adjacent to a parking lane. Both documents stipulate a lane width requirement of between 1.2-2.5m. CROW specifies lanes narrower than 1.2m pose significant safety risks to cyclists and recommends a kerb-separated, dedicated cycle track. Bicycle lanes alongside parallel motor vehicle parking are not recommended.

70 and 80kph roads: Recommendations differ significantly on high-speed arterial roads. Austroads allows on-road cycling provisions without separation, whereas CROW stipulates that on-road bicycle infrastructure is not permissible for speeds of 70kph and above. Austroads recommends an on-road bicycle lane with desirable minimum width of 2m but also permits a wide kerbside traffic lane with desirable minimum width of 4.5m. CROW requires high-speed roads to have either a separated cycle track adjacent to the road, or a service road on the same alignment.

Intersections

There are several important distinctions about intersection road user hierarchy between the Australian and Dutch approaches.

Austroads guidelines primarily consider cyclist safety at intersections, listing a range of key concerns: squeeze points; left-turning vehicle conflicts; areas where motor vehicles converge or diverge; lack of continuity in protected infrastructure and, gaining position to turn right. The Dutch approach begins with safety and extends to include all five requirements for cyclist amenity with detailed intersection treatments. A roundabout is almost always the preferred intersection type with signalised intersections only suitable for high traffic volumes (10,000-30,000 motor vehicles/day), providing inferior safety outcomes to roundabouts.

Signalised: Austroads provides a range of intersection layout plans to mitigate safety concerns. Both documents recommend bicycle lanes on approach to a signalised intersection. The notable difference is a physical kerb barrier separating cyclists and motorists in the Dutch treatment.

Unsignalised: Both guidelines show bicycle lane continuation through an unsignalised T-intersection. Solid linemarking changes to dashed across the intersection, and pavement colour may be applied. Alternatively, CROW details a separated cycle track, skewed away from the major leg across an intersection, allowing vehicle stacking space on the minor leg.

On-Road Naturalistic Case Studies

Case Study 1: Link from major off-road cycling corridor to the University

Figure 3 shows the segment classifications along Case Study 1 and Table 1 details compliance with Australian and Dutch guidelines. Of the 4.3km surveyed, half (51%) was not compliant with Austroads standards. Five segments were Austroads compliant and provisions at three intersections were non-compliant.

On six non-compliant segments, cyclists must share the lane with high-speed traffic or ride on the footpath (illegal in Victoria) (segments 4, 14; 6, 12; 8, 9). Cycle travel was classified as comfortable in bicycle lanes. In segments where conditions positioned cyclists alongside parked cars, caution was taken to ride outside the car door zone (segments 5, 11).

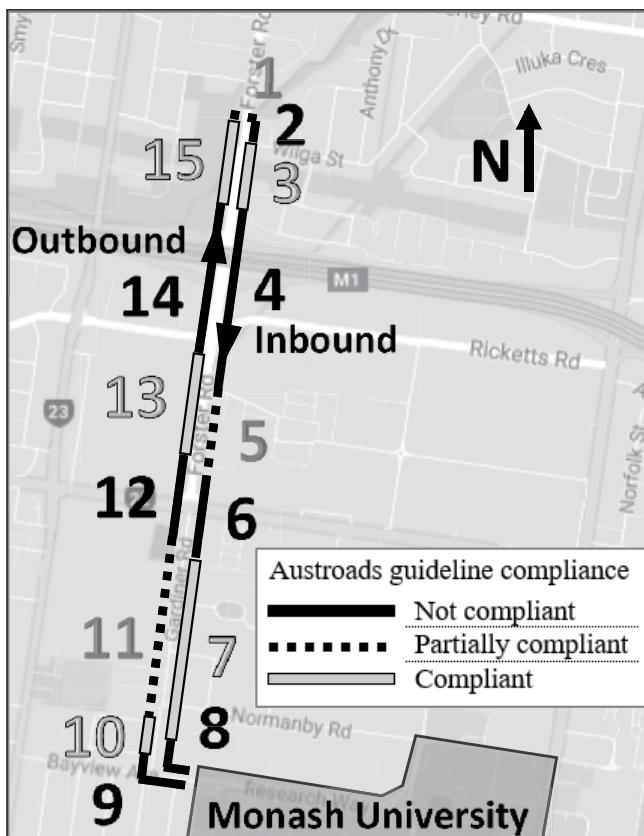


Figure 3. Case Study 1 classification
(Source: Google Maps, 2017)

Two intersections were noted points of perceived low safety. 1) Monash Freeway, due to confusion caused by unclear/lack of signage (segments 4, 14). 2) Ferntree Gully Rd, due to concern for vehicle conflicts (segment 6) and while queuing among traffic and when leaving the hold line after the traffic signal turned green (segment 12).

Case Study 2: Local streets from Clayton train station to the University bus interchange

Of the 2.0 km surveyed, the majority of the route was not compliant with Austroads standards (60%). No segments were partially compliant (Figure 4). There is currently no dedicated bicycle infrastructure along on this route. Segments 17, 20 and 22 are deemed compliant as shared-priority local roads with low speeds and low traffic volumes.

Safety outcomes are not met on Segment 18 due to frequent short-term parking movements and the narrow cross-section with a high potential for conflicts.

Segment 19 was not compliant due to potential high traffic volumes. Intersections between local road segments are generally non-compliant due to lack of shared priority markings. Speed bumps were effective in slowing traffic, and the narrow road width appeared to discourage unsafe overtaking manoeuvres.

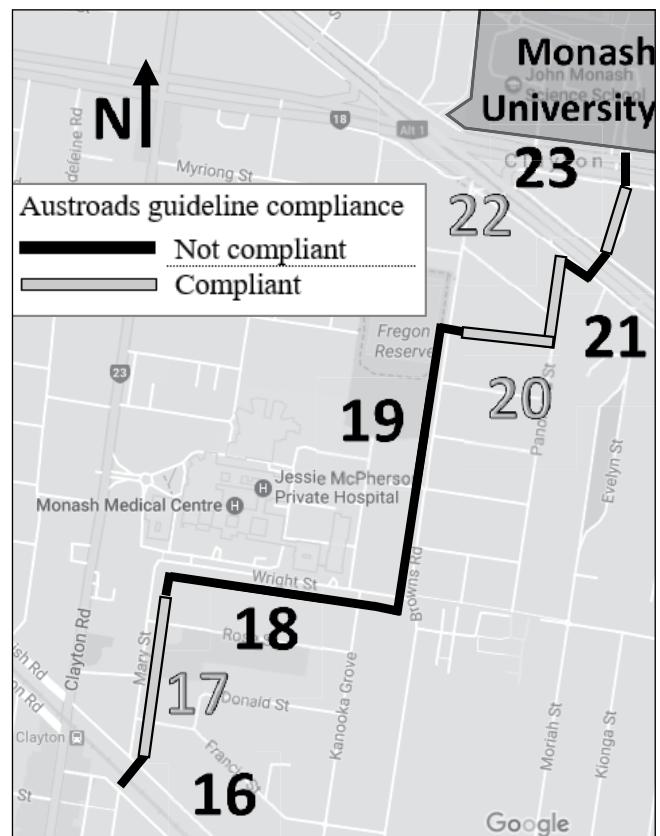


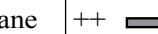
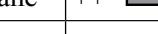
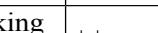
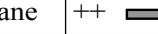
Figure 4. Case Study 2 classification
(Source: Google Maps, 2017)

There are currently no cycling provisions at the two major intersections (segments 16, 21). Within Segment 23, cyclists share a signalised crossing with high volumes of pedestrians. Perceived safety was low along segments 16 and 21 due to the lack of crossing facilities. These points are major barriers along this route.

Discussion

The differences in philosophy between the Dutch approach and the Australian approach for positioning cyclists on the road reflects differing historical, cultural and political factors underpinning current road safety practices in the two countries. These differences were explored by Pucher and Buehler (2008) who reported that The Netherlands are set apart through right of way legislation, cyclist and motorist education programs and cycling promotion efforts, alongside measures to de-incentivise motorised transport. Key elements of the Australian approach are contrasted below. In addition, the inclusion of the case studies extends this study beyond a theoretical review to practice and identifies some of the gaps between best practice (Dutch), approved practice (Austroads) and reality (on-road).

Table 1. Case Study 1 Mid-block and intersection connectivity

Seg.	Length (m)	Speed (kph)	AADT (vpd)	Current provisions	Austroads		Dutch (CROW)	
					Exclusive lane	Cycle track	Exclusive lane	Cycle track
1	• • •	20	60	-	No bike priority	-	-	-
2	—	120		2600	None	++	+	++
3	—	130		5400	2.5m exclusive lane	++ 	+	++
4	—	615		None	++	+	+	++
5	• • •	165		1.4m bicycle lane, 2.2m adjacent parking lane	++	+	+	++
6	—	310		-	None	++ 	++ 	
7	—	630	50	-	1.8m exclusive lane	++ 	+	++ 
8	—	185		-	None	+	++	++
9	—	215		-	None	++ 	++ 	
10	—	185		—	1.8m exclusive lane	++ 	+	++ 
11	• • •	425		—	2.2m shared parking lane	++ 	++ 	+
12	—	280	60	5400	None	++ 	++ 	+
13	—	295		—	1.6m exclusive lane	++ 	+	++ 
14	—	500		—	None	++ 	+	++ 
15	—	260	60	2600	2.2m exclusive lane	++ 	+	++ 

Legend: ++ Optimal outcome; + Potentially suitable outcome; x Unsuitable outcome; - Not available

Table 2. Case Study 2 mid-block and intersection connectivity

Seg.	Length (m)	Speed (kph)	Current provisions	Austroads		Dutch Guidelines	
				Mid-block	Intersection		
16	—	20	60	None Unsignalised	N/A	Separated POS	Raised, separated cycle track crossing
17	—	320	40	40kph speed	40kph shared	N/A	30kph, shared bicycle/car priority
18	—	490	50	None Parking lane	40kph shared	Sharrows	30kph, shared bicycle/car priority Separated parking lane
19	—	495	50*	None	Exclusive lane	Sharrows	Exclusive lane or cycle track
20	—	350	50*	None	40kph shared	N/A	30kph, shared bicycle/car priority
21	—	110	80	None	Contra-flow lane	Separated POS	POS or grade separated crossing
22	—	130	50*	None	40kph shared	N/A	30kph, shared bicycle/car priority
23	—	80	80	Shared POS	Bike priority	Separated POS	POS or grade separated crossing

Legend: 40 - Posted 40kph; 50* - Default 50kph; POS - Pedestrian Operated Signals; N/A - Not applicable

Comparison of Bicycle Planning Approaches

Bicycle planning in The Netherlands is based on their five main requirements. These principles prioritise cyclists as well as recognising their physical vulnerability.

Australia's current road management approach is built on the four pillars of "Safe System" (safe roads, safe speeds, safe vehicles and safe people). The *National Road Safety Strategy* seeks to reduce the likelihood and severity of road crashes through targeting these four pillars (TIC, 2010). The Safe System approach is predominantly incorporated in Australian design guidelines through safe roads and safe speeds. Safe vehicles requirements offer some protection to cyclists (e.g. Auto Emergency Braking) but this is undermined as motor vehicles currently being rated by the ANCAP tests as 'five star', are rated as marginal in pedestrian protection tests (ANCAP, 2017). Safe people can be targeted through policy and education programs and importantly safe behaviour can be an outcome of responding to inclusive infrastructure.

Safety

At a policy level, the Australian strategic framework has a strong emphasis on safety. However, several aspects of the guidelines for mid-block and intersection bicycle infrastructure did not meet Dutch best practice recommendations. Furthermore, treatments for cyclists on roads assessed in the study locale did not reflect Austroads guidelines or Safe System strategic outcomes.

Pucher and Buehler (2017) compared trends in cyclist fatalities per 100 million km travelled in the Netherlands, Denmark, the United Kingdom and the USA to demonstrate the relative safety of Dutch cycling. Johnson (2010) reported that Australian cycling data is limited and problematic and unlikely to accurately determine a comparable fatality rate. This is a significant gap in Australian data and should be filled to inform and guide widespread reform to improve outcomes for cyclist safety.

Cohesion and directness

The CROW manual targets the network holistically when designing and recommending site-specific treatments. Facilities must link up to provide a holistic route, and provide directness in both space and time. Austroads guidelines were found to have less focus on continuity, with some discussion of spatial route directness but no consideration for time.

Both case study routes were lacking in terms of cohesion and directness. Bicycle facilities are disconnected along the Case Study 1 route, and the Case Study 2 route is not spatially direct. Indirectness has negative impacts on participation and route selection (Buehler and Dill, 2016; Monsere et al, 2012).

Comfort and attractiveness

The Dutch approach seeks to address barriers to cycling by prioritising comfort and attractiveness when planning the bicycle network. At a policy level, Australian strategic documents reproduced these principles, however, they are not applied in the guidelines for specific infrastructure types.

In the case study routes, some segments were intimidating to an experienced cyclist with low perceived safety reported in several instances. It is recognised that user comfort is inherently personal (Monsere et al, 2012), however, it is probable that less experienced cyclists would find the routes less attractive and experience discomfort when using them.

Comparison of On-Road Infrastructure

Local streets

Local streets in The Netherlands have 30kph speed limits, and cyclists share priority with drivers. Austroads has some provision for low-speed, shared priority local streets with 40kph speed limits. However, the 50kph default urban speed limit was identified on most local streets in the study area. Austroads guidelines do not recommend specific cycling treatments for 50kph local streets, despite the importance of speed in protecting vulnerable road users under the Safe System approach.

The Case Study 2 route requires upgrading to meet Austroads principles and fulfil its role as a Strategic Cycling Corridor. Speed limits need to be reduced to 40kph along the entire route to achieve the "safe speeds" target. Car parking should be indented and separated from traffic lanes by a critical reaction strip, to provide a "safe roads" environment. Finally, bicycle priority pavement marking and signage should be installed to increase messages to road users and encourage "safe people" behaviours.

Mid-block treatments

Guidelines were found to differ in their prescription of on-road versus separated bicycle lanes. The Dutch are absolute in their recommendations for mid-block separation between bicycles and other road users. Cycling on major roads is discouraged through the provision of alternative routes which are more attractive and equally direct.

In contrast, Australian strategies have far less focus on separation. Austroads permits a wide kerbside traffic lane on roads with up to an 80kph speed limit, which bicycles share with motor vehicles with no physical separation, line-marking or signage. This does not comply with safe speeds or safe roads principles.

Bicycle lanes are recommended for a wide range of road types and speeds, and were observed to be the predominant mid-block treatment within the study area. However, research into hospital admissions from on-road cycling crashes revealed that cyclists were traveling in a bike lane in almost a quarter of crashes (Beck et al, 2016). This evidences the idea that some infrastructure types do not achieve the Safe System goal of reducing crash severity.

Accordingly, Austroads guidelines require amendment to encourage physical separation as a first priority. The alternative requirement should be marked, exclusive bicycle lanes with adequate width and buffer from parked cars. Such a focus could align guidelines with Australian safe roads principles.

Intersection treatments

The Dutch approach favours roundabouts to deliver infrastructure which prioritises and eases bicycle transport. Their primary concerns with signalised intersections include cyclist convenience, comfort and directness in time.

The historic approach to major intersection planning in Australia favours signalised intersections over roundabouts, and no roundabouts were observed on major roads within the study area.

Austroads guidelines encourage continuity of bicycle infrastructure at traffic signals, but these treatments were not found in the study locale. Where Forster Rd intersects Ferntree Gully Rd on the Case Study 1 route (segments 6 and 12), mid-block bicycle lanes terminate prior to the intersection, forcing cyclists to mingle with traffic. This situation is found widely across the Australian cycling network (Johnson, 2011; Thompson, 2010) and highlights the shortcomings of past guidelines in meeting safe roads objectives.

Approach and departure bicycle lanes were recently added at an existing intersection in the City of Glen Eira (2010). This demonstrates that some municipalities are willing to reclaim road space from motor vehicles, a stance which is needed across the wider cycling network to protect cyclists and achieve safety targets.

While there are clear socio-political differences in how cycling has been provided for in the Netherlands compared to Australia, the Dutch approach provides a model that can be applied in the Australian environment. Its suitability is already identified as the five fundamental Dutch requirements are named in the preface of Australian policy documents but as yet are not being incorporated into guidelines and practice. For example, a recent review reported that the National Road Safety Strategy ‘provides little more than passing references to cyclists...[and offers] few suggestions about how to apply Safe System principles to promote cycling safety in the broader context of the transport system’ (Lydon et al, 2015; p5). From this study, it is evident that greater integration of the Dutch approach into the Australian guidelines is an important step towards promoting cycling safety in the transport system in Australia.

Strengths and limitations

The main strength of this study is that it provides a direct comparison between the current Australian guidelines to the Dutch best practice approach, both theoretically and on-road. There are gaps in the way cycling is provided for in Australia and this review provided new insights in terms of both the theory and practice. These insights can help to inform how cycling provisions need to be included

in Austroads guidelines and broader road safety policy in Australia.

The main limitation of this study was that we only compared the Australian approach to one international model. Albeit the Dutch approach is a leading example, there are other international approaches (e.g. Denmark, United Kingdom, parts of the United States of America e.g. Portland) that would have offered further insights. Multi-country analysis was beyond the scope of this study but will be explored in future research. Also, the case study routes provide a limited selection of infrastructure provisions across wider Melbourne and Australia. Further research that assessed additional infrastructure types would address this limitation.

Conclusions

The Australian cycling infrastructure planning framework states it has a focus on safety. However, the Dutch best practice approach includes supplementary factors which target other barriers to cycling and improve cyclist amenity. Australian cycling infrastructure design guidelines did not wholly reflect the overlying Safe System principles. Some allowed infrastructure types compromise cyclist safety, as evidenced by crash studies.

Existing bicycle facilities in urban areas often do not comply with current Australian design guidelines. Problems include unsafe or non-existent intersection and mid-block treatments, leading to disconnected routes. Infrastructure upgrades linking discontinuous routes, such as Case Study 1, should be prioritised to increase cyclist amenity and align bicycle networks with the safe roads pillar of the Safe System approach. Local streets lie on major cycling routes for a range of cyclist abilities, such as those in Case Study 2, and should be targeted for speed limit reduction and shared priority measures.

The study of case study routes could be extended temporally to assess the success of future upgrade works in aligning case study routes with Australian guidelines. Further, before-and-after cyclist counts and intercept surveys could identify changes to ridership and perceived safety.

Alternative future research should seek to assess a wider range of routes servicing major destinations. Strategic Cycling Corridors, the target of future funding in Victoria, should be prioritised for assessment.

Acknowledgements

The authors wish to thank Carly Hunter of VicRoads for the opportunity to attend a planning workshop. Thanks to Teije Gorris and Paul van den Bosch of DTV Consultants (the Netherlands) and Dr Hafez Alavi of the TAC for their expert advice at this workshop. Staff at the Monash University Buildings and Property Division provided survey data and advised generally on bicycle infrastructure priorities near the University.

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Development of a pedestrian injury prediction model for potential use in an Advanced Automated Crash Notification (AACN) system

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This peer-reviewed paper was first presented at the 2017 Australasian Road Safety Conference (ARSC2017) held in Perth, WA, Australia and first published in the ARSC2017 Proceedings as a peer-reviewed 'Full Paper'. It underwent further peer-review by three independent experts in the field. It is being reproduced here with the kind permission of the authors and is now only available in this edition of the JACRS.

Key findings

- Three pedestrian injury risk prediction models were developed in this study
- A mass crash data model was validated using in-depth crash data
- This model could theoretically be used in a pedestrian AACN system
- A refined model could potentially improve pedestrian collision injury outcomes
- Such a model would need to be widely deployed in an AACN system to be effective

Abstract

Advanced Automated Crash Notification (AACN) systems can inform emergency services of a serious road crash with minimal delay, giving the precise location of the crash and transmitting key information from the vehicle's event data recorder, including: the crashed vehicle's delta-V (vehicle change in velocity resulting from the crash), occupant seatbelt use, airbag deployment, and travelling speed. This information can be used to determine the likelihood of serious injury within the crashed vehicle using a suitable injury prediction algorithm. The purpose of this study was to examine two pedestrian crash data sets to develop pedestrian injury risk models using logistic regression analysis. Vehicle speed was used as the predictor variable and injury outcome was the response variable. The crash data used was from the in-depth crash database collected by the Centre for Automotive Safety Research (CASR) and from the South Australian Traffic Accident Reporting System (TARS) mass crash database. Three injury prediction models were developed and a discussion of the data and models are presented. Ultimately, the TARS data injury prediction model was selected as the most suitable injury prediction model, and this model was validated with the CASR in-depth data using receiver operator characteristic analysis. Suitability of the final model for use in a pedestrian AACN system was assessed using an injury threshold analysis. By accepting an injury underestimate rate of 10%, the minimum threshold for injury (for an AACN system activation) is 23%, which occurs at a vehicle speed 23 km/h; the corresponding injury over-estimation rate was 84%.

Keywords

Pedestrians, Injury Prediction, Advanced Automatic Crash Notification, Collision

Introduction

In the period 2000 to 2013, there were 1,788 people killed and 17,405 people seriously injured in road crashes in South Australia (Department of Planning, Transport and Infrastructure, 2017) from a population of approximately 1.7 million people (Australian Bureau of Statistics, 2017). Pedestrians accounted for 11.5% (n=205) of the fatalities and 8.7% (n=1507) of the serious injuries. Also over this period there has been a steady decline in pedestrian injuries.

Lowering of urban speed limits has resulted in reductions in pedestrian injuries in SA (Anderson, 2008) and improvements in vehicle design, have also led to improved

injury outcomes for pedestrians (Strandroth, Rizzi, Sternlund, Lie & Tingvall, 2011). Post-crash notification of collisions involving pedestrians is one area in road safety that is still overlooked. Currently, a physical phone call must be made to emergency services and details and location of any pedestrian collision must be verbally conveyed from a caller to a call taker, before an emergency medical response can be activated. This can cause delays with emergency response, particularly if there is a delay in an emergency call being made, or there are issues with conveying the precise location of the crash.

Advanced Automatic Collision Notification (AACN) systems have the potential to automatically notify emergency medical services of a crash and transmit the precise location of that crash, along with various data that might be captured by a vehicle's event data recorder (EDR). Data captured on EDRs may include delta-V, vehicle pre- and post-crash speed and potentially, other vehicle variables consistent with the specifications given by the National Highway Traffic Safety Administration¹ (National Highway Traffic Safety Administration, 2006). Generally, only crash events of a sufficient magnitude (for example, a crash that might involve the deployment of an airbag) would trigger an event to be recorded by an EDR.

Advanced Automated Crash Notification (AACN) systems already exist in certain vehicle models. After a crash is detected, vehicles with these systems can automatically transmit GPS location and delta-V to emergency services and this can be used to predict occupant injury levels (Champion et al., 2004; Kononen, Flannagan & Wang, 2011; Nishimoto et al., 2017). This theoretically may improve occupant injury outcome by way of improved emergency activation and response. Pedestrians and other vulnerable road users may also benefit from the development of an AACN injury prediction model and some initial research has already commenced in Japan (Nishimoto, Mukaigawa, Tominaga & Kiuchi, 2015).

Detection of pedestrian crashes however, is difficult, as it requires specialised contact sensors similar to those discussed in Fredriksson, Haland and Yang (2001) and Ito, Mizuno, Ueyama, Nakane and Wanami (2014) or non-contact pedestrian detection sensors such as those discussed in Oikawa, Matsui, Doi and Sakurai (2016). Some pedestrian impact sensors already exist in vehicles that deploy the vehicle's bonnet to mitigate pedestrian head injury in a pedestrian collision, for example, the 2015 Mazda MX-5 (Mazda, no date).

Significant efforts have already been undertaken by vehicle manufacturers to protect or mitigate the injuries sustained by pedestrians in collisions, these are in part, a result of EuroNCAP requirements (EuroNCAP, 2014). Further efforts will need to be undertaken by manufacturers to develop systems that can accurately detect pedestrian impacts. This is particularly important when a pedestrian's tolerance to injury is likely to be exceeded, which may occur when vehicle speeds in collisions exceed those specified by EuroNCAP (2014) for protection or injury mitigation.

Vehicle speed in a pedestrian collision influences pedestrian injury severity (Davis, 2001; Rosén & Sander, 2009). Knowing the vehicle speed can assist with injury prediction by emergency medical services if it can be transmitted easily from a vehicle event data recorder (EDR), post-crash, to emergency services (Champion et al., 2004; Kononen, et al., 2011; Nishimoto et al., 2017). An AACN system based on pedestrian crash data could potentially be a beneficial future vehicle technology.

¹ There are no specifications under any vehicle design rules that require vehicle manufacturers to make EDR data available in Australia. However, some vehicles in Australia do have data available for download, as a consequence of the NHTSA's specifications.

The aim of the present study was to develop a proof-of-concept AACN pedestrian injury prediction model using two sources of road crash data from South Australia: mass police-reported crash from TARS and the CASR's at-scene in-depth crash data.

Data

Two sources of data were used in this study, mass crash data and in-depth data. The proceeding section briefly discusses each of these data sources.

Mass crash data

SA police must be notified of, and attend, any crash involving injury or significant property damage. Additionally, SA police are responsible for preparing a vehicle collision report (VCR) that includes various driver and vehicle details, the severity of injury sustained by people involved and an estimate of the speed of vehicles involved in the collision. Data from the VCRs are re-coded with additional crash information into the South Australian Traffic Accident Reporting system (TARS), maintained by the SA Government Department for Planning, Transport and Infrastructure.

Mass crash data from the TARS for the years 2000 to 2013 (for pedestrian crashes involving a single vehicle only) were used in this study as one data source. Cases were only included if a police reported vehicle speed was available ($n=4,312$). The speed data from TARS is the police estimated speed of a vehicle prior to the collision with a pedestrian, and can be made by police judgment or based on driver or witness statements. In some situations the speed in TARS may be the vehicle travel speed or the vehicle impact speed, depending on any evasive action taken or reported by a driver. There are four injury categories in TARS; fatal (death resulting from crash injuries within 30 day of a crash), admitted to hospital (treatment at an emergency hospital for 24 hours or more), treated at hospital (treatment at an emergency hospital for less than 24 hours and not admitted), private doctor (medical treatment or consultation at a non-emergency medical facility).

At-scene in-depth crash data

Independently of SA Police, The University of Adelaide's Centre for Automotive Safety Research (and the Road Accident Research Unit and Traffic Accident Unit before it) has been involved in at-scene in-depth crash investigation since the 1960's (McLean & Ryan, 1965, Baldock et al., 2009). The benefit of at-scene in-depth crash investigation is that very detailed information is collected and is used to reconstruct crashes, allowing for determination of vehicle speeds with greater precision (Kloeden, McLean, Moore & Ponte, 1997). The reconstruction methods used to determine the impact and travel speeds in the in-depth pedestrian crash data are documented in Kloeden et al., (1997). Hospital records pertaining to the pedestrians injured

were also examined to code injury severity according to the Abbreviated Injury Scale (AIS; Association for the Advancement of Automotive Medicine, 2005).

As mentioned, the CASR in-depth reconstructed speed data includes vehicle travel speed and vehicle impact speed for each pedestrian collision. The speeds are based on all at-scene evidence available immediately after the crash such as skid marks, scuff marks and pedestrian throw distances or, in the absence of all other information, based on driver or witness estimates (21% of cases). In some crashes, in the absence of any evasive action by a driver, the travel and impact speeds are equivalent.

Pedestrian crashes investigated as part of CASR's at-scene in-depth crash investigation program (1999-2005) were used as the second data source. Cases in which vehicle travel speed could be determined and a coded injury severity (AIS; AAAM, 2005) were used in the analysis. The AIS is used to code and rank individual body injuries sustained in traumatic events such as road crashes. Consistent with this, the CASR at-scene in-depth study database contains quantitative injury data coded using AIS, from which the highest valued or maximum AIS, (MAIS - indicating the highest threat to life body injury) can be derived.

Method

Initially, the injuries in each dataset were examined and then categorized into two levels of severity 'serious injury' and 'minor injury'. As the in-depth crash data is also subset of the mass crash data, a comparison of coded injuries and vehicle speeds in each of the data sets was undertaken based on the individual crashes that were found in both datasets.

Utilizing the two sources of data, three pedestrian injury prediction models were developed using logistic regression analysis. This was done, in part, to explore and assess the effectiveness of the different datasets, and to see if they were somewhat consistent with their injury prediction. Three cut-off values for injury severity were used, as serious injury severity assessment can subjective and this allowed a further exploration of the data sets.

It is acknowledged that several factors influence risk of injury to a pedestrian in a collision (e.g. age, gender, vehicle year etc.), however, for this study, vehicle travel speed (a function of impact energy) was used as the single pedestrian injury risk predictor variable. The probability of injury (injury risk) for each model was $p(Y=1 | x)$, where travel speed was the predictor variable.

$$p = \frac{1}{1 + \exp[-(\beta_0 + \beta_1 x)]} \quad (1)$$

The response variables for the various injury prediction models were:

- Model 1: Y=1 for MAIS 2+ and Y=0 for MAIS 1
- Model 2: Y=1 for MAIS 3+ and Y=0 for MAIS 1 and 2
- Model 3: Y=1 for TARS serious injury and Y=0 for TARS minor injury.

Results

TARS crash data compared to in-depth crash data

The 4,312 pedestrian crashes from TARS were disaggregated into serious injuries (hospital admission; n=1,065 and fatal; n=119) and minor injuries (hospital treated; n=2,360 and private doctor treated; n=768). In comparison, the CASR in-depth speed/injury dataset consisted of a total of 84 pedestrian crashes with the following injury classification: MAIS 1 (n=35), MAIS 2 (n=23), MAIS 3 (n=8), MAIS 4 (n=7), MAIS 5 (n=7) and MAIS 6 (n=4).

While the in-depth crash database maintained by CASR contains a detailed sample of crashes in SA, the TARS mass crash database contains details of all crashes that have occurred in SA. Data from CASR can be matched with data in TARS to determine the correlation between MAIS and TARS recorded injury, as well as reconstructed CASR vehicle speeds and the estimates of vehicle speed in TARS.

TARS injury data compared to in-depth injury data

The relationship between MAIS from the CASR in-depth database and TARS injury categories is shown in Figure 1. A considerable proportion (80%) of the pedestrian MAIS 1 injuries in the CASR in-depth sample corresponded to minor injuries in TARS database (private doctor and treated at the hospital) with the remaining 20% of MAIS 1 injuries corresponding to TARS admitted to hospital category of injury.

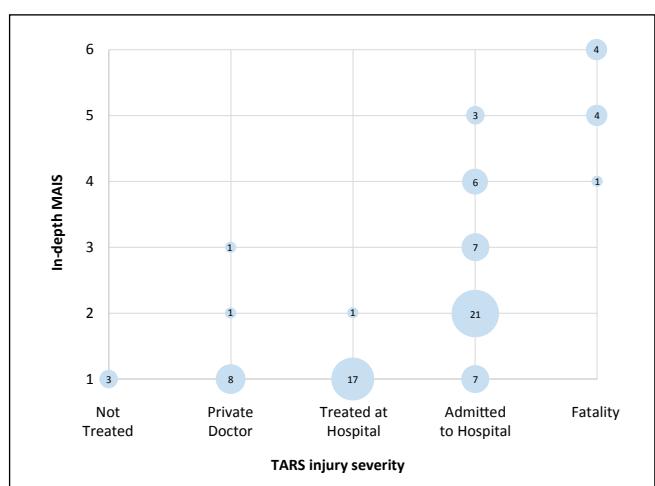
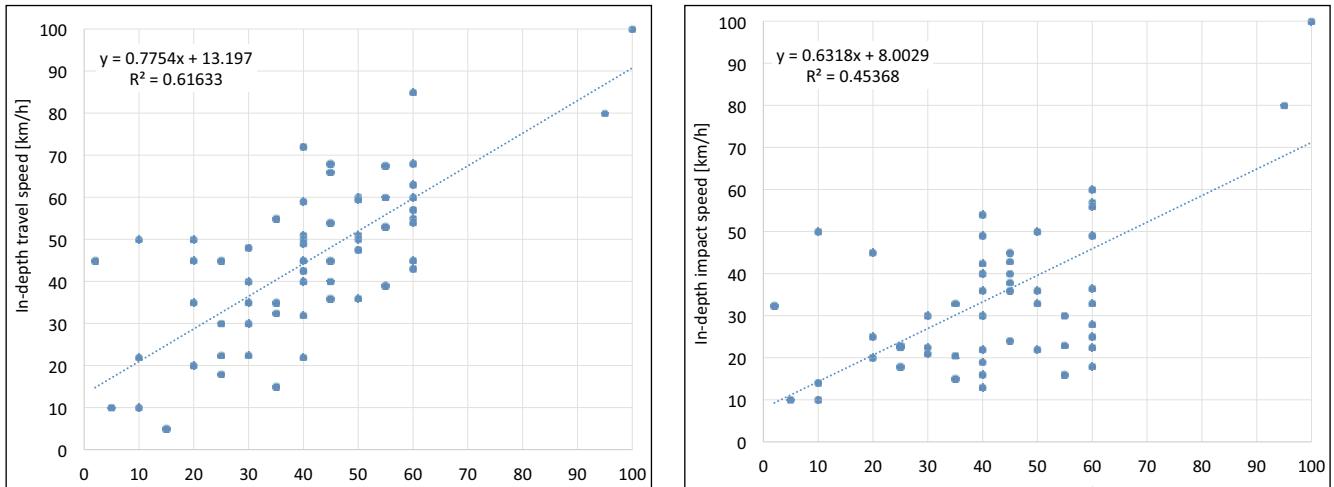


Figure 1. In-depth injury severity vs TARS injury severity.



**Figure 2. (a) In-depth travel speed vs TARS speed (n=84);
(b) In-depth impact speed vs TARS speed (n=62).**

A majority of number MAIS 2 injuries (87.5%) were associated with TARS admitted to hospital injuries. Generally, MAIS 2 – 5 injuries were associated with TARS admitted to hospital category and the remaining MAIS 4 + injuries ultimately resulted in a fatality.

In-Depth Speed Compared To TARS Recorded Vehicle Speed

It was not clear whether the speed data in TARS was more aligned with vehicle travel speed or impact speed, so a comparison was made with cross-matched CASR travel and impact speeds. Figure 2 (a) shows the CASR in-depth travel speed compared to TARS speed while Figure 2 (b) shows the CASR in-depth impact speed compared to TARS speed. While not showing exceptional correlation, TARS speed does correlate better with the CASR in-depth travel speed

values ($R^2 = 0.6163$ for travel speed compared with $R^2 = 0.4537$ for impact speed). It was assumed then that travel speed was the reported variable in TARS.

Logistic regression results

The coefficients, standard errors and p-values resulting from the logistic regression are shown in Tables 1, 2 and 3. Each of the three regression models had low p-values ($p < 0.005$), indicating a statistically significant relationship between speed and pedestrian injury severity.

Injury risk curves for pedestrian crashes

Each of the logistic regression models can be used to plot injury risk curves. These risk curves show the relationship between vehicle travel speed and the probability of a pedestrian collision resulting in a specific injury level. The

Table 1. Logistic regression model 1, Y=1 for MAIS2+ (n=49) and Y=0 for MAIS 1 (n=35)

Risk factors	Coefficients	Standard Error	p-value
Intercept (β_0)	-2.419	0.809	0.003
Travel speed (β_1)	0.062	0.018	<0.001

Table 2. Logistic regression model 2, MAIS3+ (n=26) and Y=0 for MAIS 1 & 2 (n=58)

Risk factors	Coefficients	Standard Error	p-value
Intercept (β_0)	-3.455	0.916	<0.001
Travel speed (β_1)	0.054	0.017	0.002

Table 3. Logistic regression model 3, Y=1 for TARS Serious Injury+ (n=1,184) and Y=0 for TARS minor injury (n=3,128)

Risk factors	Coefficients	Standard Error	p-value
Intercept (β_0)	-1.934	0.066	<0.001
Travel speed (β_1)	0.031	0.002	<0.001

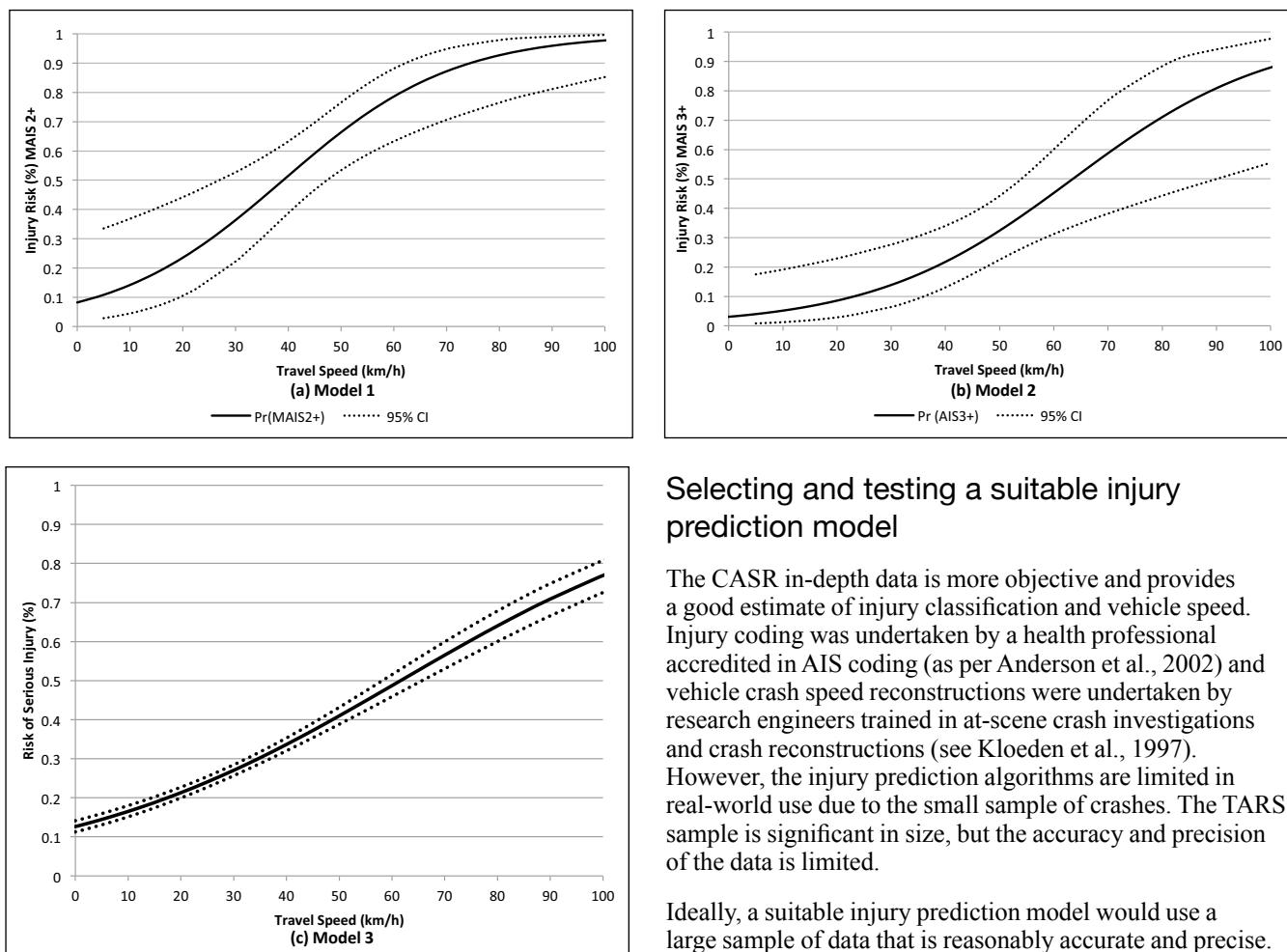


Figure 3. Pedestrian injury risk curves with 95% Confidence Intervals (Pezzullo, 2015) according to travel speed in-depth data for MAIS2+ (a), MAIS3+ (b) and TARS data (c).

injury-risk curves for each of the three models (and the corresponding 95% confidence intervals for the data) are shown in Figures 3 (a), (b) and (c). In a pedestrian collision where a vehicle involved had been travelling at 60 km/h, the likelihood of MAIS 2+ injury (model 1) would be around 79% [95% confidence interval: 63% to 88%] and the likelihood of MAIS 3+ injury (model 2) would be around 45% [95% confidence interval: 31% to 60%]. For model 3 a 60 km/h travel speed corresponds to a 48% risk of a serious injury [95% confidence interval: 46% to 52%].

Table 4. Classification matrix for ROC analysis

		Model 3 Injury Prediction	
		Predicted Positive	Predicted Negative
Actual Injury Severity	Actual Positive MAIS2+	True Positive (TP) <i>Pedestrian serious injury correctly predicted to be a MAIS2+</i>	False Negative (FN) <i>Pedestrian serious injury incorrectly predicted to be a MAIS1 (under triage)</i>
	Actual Negative MAIS1	False Positive (FP) <i>Pedestrian minor injury incorrectly predicted to be a MAIS2+ (over triage)</i>	True Negative (TN) <i>Pedestrian minor injury correctly predicted to be a MAIS1</i>

Selecting and testing a suitable injury prediction model

The CASR in-depth data is more objective and provides a good estimate of injury classification and vehicle speed. Injury coding was undertaken by a health professional accredited in AIS coding (as per Anderson et al., 2002) and vehicle crash speed reconstructions were undertaken by research engineers trained in at-scene crash investigations and crash reconstructions (see Kloeden et al., 1997). However, the injury prediction algorithms are limited in real-world use due to the small sample of crashes. The TARS sample is significant in size, but the accuracy and precision of the data is limited.

Ideally, a suitable injury prediction model would use a large sample of data that is reasonably accurate and precise. Mass road crash data is routinely available, so the TARS injury prediction model (model 3) was selected as the suitable injury prediction model, and was evaluated against the CASR in-depth crash data, using receiver operator characteristic (ROC) analysis.

The test data consisted of the 84 pedestrian crashes in the CASR in-depth crash database that could be matched with the TARS sample of pedestrian crashes (as described previously). MAIS 2+ was used as the serious injury threshold ($N=49$) for the in-depth data while MAIS 1 ($N=35$) was considered as the minor injury threshold. This seemed most appropriate given the association between MAIS2+ injuries and hospital admission. Since model 3 was developed to predict the probability of a serious injury

resulting from a pedestrian collision, the sensitivity and specificity can be calculated based on how effective model 3 is at classifying injury. Table 4 shows the classification matrix for the ROC analysis for the four categories of prediction that can be made by model 3.

The sensitivity (true positive rate) of the algorithm (equation 2) is the rate of the true positives compared to true positive and false negatives, that is, how often the model correctly predicts actual serious injuries. The specificity (true negative rate) of the model (equation 3) is the rate of the true negatives compared to true negatives and false positives, that is, how often the algorithm correctly predicts minor, rather than serious, injuries. The false positive rate, can be determined using equation 4.

$$\text{Sensitivity} = \frac{TP}{TP+FN} \quad (2)$$

$$\text{Specificity} = \frac{TN}{TN+FP} \quad (3)$$

$$1 - \text{Specificity} = 1 - \frac{TN}{TN+FP} = \frac{FP}{TN+FP} \quad (4)$$

The ROC curve of sensitivity (vertical axis) against 1-Specificity (horizontal axis), or the true positive rate against the false positive rate, is shown in Figure 4. The injury prediction model has a sensitivity value of 1.0 only when 1-Specificity also has a value of 1.0 in Figure 4. This represents a scenario in which all genuine pedestrian serious injuries in the CASR in-depth sample were correctly predicted by the TARS model to be serious injuries, however, this also resulted in all genuine pedestrian minor injuries incorrectly predicted by model 3 as serious injuries. In this situation there would be a high level of over-triage, or lack of triage, as all injuries are predicted to be urgent.

A decrease in the sensitivity of the model from a value of one introduces a level of under-triage while concurrently decreasing over-triage. Under-triage occurs when the level of emergency medical care is under-estimated and a seriously injured pedestrian is given a lower level of medical treatment, which may potentially result in an adverse injury outcome. Conversely, over-triage occurs when the level of

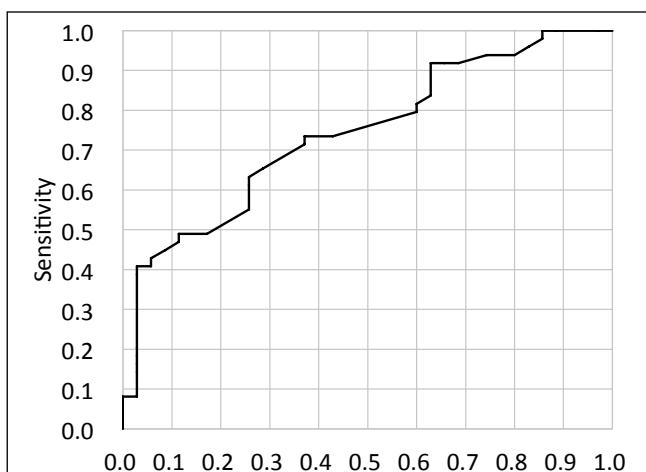


Figure 4. ROC curve for model 3, tested using matched in-depth cases

emergency medical care is over-estimated and a pedestrian with minor injuries is given a higher level of medical treatment than might be needed, resulting in inefficient use of medical resources.

Hence, depending on what levels of under- and over-triage can be tolerated, the ROC curve indicates various levels of triage threshold. The accuracy of the model can be determined by analysing the ROC curves, or more specifically the area under the curve (referred to as AUC). The AUC can vary from 0.5 (values occurring by chance alone) 0.7-0.9 (moderately accurate), greater than 0.9 (high accuracy) and up to 1 (perfect test) (Fischer, Bachman & Jaeschke, 2003).

The ROC curve in Figure 4 is not a smooth curve due to the limited number of CASR in-depth cases ($n=84$) available for verification of model 3. Nevertheless, the AUC was determined to be 0.743 for model 3, hence it can be considered moderately accurate.

Injury thresholds for model 3 for use in AACN systems

Before the predictive model can be used in an AACN system, the optimal injury thresholds for notifications need to be determined so that occurrences of under-triage and over-triage are minimised. The under-triage rate and over-triage rates can be calculated using equations (5) and (6) respectively where the denominators and numerators are previously defined in Table 4.

$$\text{Under-triage rate} = \frac{FN}{TP+FN} \quad (5)$$

$$\text{Over-triage rate} = \frac{FP}{TN+FP} \quad (6)$$

Further, the ‘fitting rate’, (equation 7) is the ratio of the algorithm’s prediction of genuine serious injuries (TP) and minor injuries (TN) to all predictions including those resulting in over- and under-triage.

$$\text{Fitting rate} = \frac{TP+TN}{TP+TN+FN+FP} \quad (7)$$

Determining the notification thresholds on the basis of an under-triage rate and over-triage rate is important. In this study, the notification threshold is determined on the basis of an acceptable under-triage of pedestrian serious injuries of 10% or less in the prediction model. In this situation, fewer than 1 in 10 pedestrian injuries might be classified erroneously as a minor injury when they might genuinely be a serious injury.

The under-triage and over-triage rate curves for model 3 are shown in Figure 5. The two rate curves in the figure are approximately inversely proportional to each other. Also shown in the figure is the fitting rate curve. For the injury prediction model, an under-triage rate of 10% corresponds to a notification threshold of 23% for prediction of a serious injury. The over-triage rate is subsequently around 84% and the hit rate around 63%. In an AACN system using model

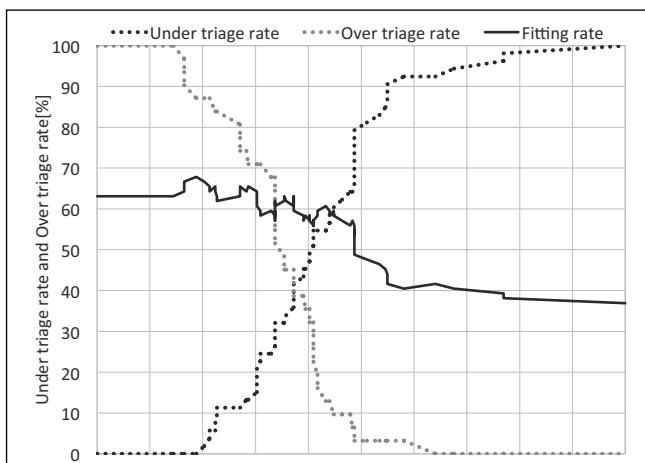


Figure 5. Relationship between threshold and triage rates for model 3.

3 to predict the likelihood of a serious pedestrian injury, the 23% threshold for the serious injury rate (for a 10% under-triage rate), corresponds to a vehicle speed of 23 km/h.

Discussion

Automatic Collision Notification and Advanced Automatic Collision Notification systems are still emerging vehicle technologies. Several types of systems have been developed and deployed to various degrees, throughout different countries, to better assist vehicle occupants in post-crash emergency response scenarios. Arguably, road user groups such as pedestrians, cyclists and motorcyclists are in greater need of immediate post-crash emergency response, particularly as they are more vulnerable to injury and are not given the same protection as a vehicle occupant in a carefully designed vehicle with a full suite of primary and secondary safety systems. As a consequence, vulnerable road users such as pedestrians are generally over-triaged by post-crash emergency responders, as there is no way of knowing the severity of a pedestrian collision with a vehicle.

An AACN system that can determine that a pedestrian collision has occurred, immediately notify emergency services of that collision and the precise location will certainly aid in quicker response. In addition, if adopted by emergency services, this basic crash information theoretically could be supplemented by one of three models proposed in this research, to predict the likely probability of an MAIS 2+ (model 1) or MAIS 3+ (model 2) or likelihood of a serious injury according to model 3. This information can be useful for emergency triaging, particularly when there might be competing demands for emergency service attendance for multiple incidents at different locations. An AACN system for pedestrians (and indeed all vulnerable road users) may also assist those injured by drivers involved in hit and run incidences with the crash, location and speed of the vehicle being transmitted even in the absence of the vehicle and driver.

The critical part in the future development of an AACN system for pedestrians is pedestrian detection. As mentioned earlier, pedestrian impacts are generally not severe enough to deploy a vehicle safety system that might trigger an event

data recording, so specific pedestrian impact detection devices (such as those mentioned previously) are required. Potentially, if integrated with vehicle EDRs, camera based autonomous emergency braking systems (where a time to collision might be such that the collision cannot be avoided) or forward collision warning systems (where the system detects a pedestrian, but the driver may not be able to stop in time and the collision still occurs) may also be useful as pedestrian detection systems for the activation of an AACN system.

The injury prediction models presented here are certainly not without limitations. The authors acknowledge that the data from the CASR in-depth crash investigations, while high in quality, are few in number. The mass crash data is limited in accuracy although being reasonably large in sample size. Additionally, the authors acknowledge that not all AIS2+ or ‘hospital admitted’ injuries are necessarily time-critical or require a rapid emergency response. Despite these limitations, an attempt was made at validating model 3 (the TARS model) with the CASR in-depth data, and the AUC of the ROC curve was determined to be 0.743 for the TARS model, which is moderately accurate according to Fischer et al., (2003).

Internationally, accepted levels of under-triage rates are between 5% and 10% and the desired level of over-triage is 50%. (American College of Surgeons, 2014; Josten et al., 2012). For model 3, an under-triage rate of 10% resulted in an over triage rate exceeding 70%. This is greater than the recommended 50% over-triage rate. The risk with such a high over-triage rate is that emergency medical resources will potentially be tasked to attend considerably more pedestrian serious injuries than might occur in reality. This is not too problematic, as pedestrian crashes in the absence of any AACN are generally over-triaged due to a pedestrian’s inherent vulnerability to injury.

Conclusions

This research indicates that the development of proof-of-concept pedestrian injury risk prediction model is feasible using South Australian crash data and provides a starting point for further development for use in a pedestrian AACN system. A validated and refined model, when combined with an AACN system, could be used to provide an initial guide to assist with medical triage and could theoretically reduce the time to initial post-crash medical treatment for those with serious injuries and subsequent emergency transport to medical facilities. For those with predicted minor injuries, time to treatment could increase. Such a system, if widely implemented, would potentially reduce pedestrian collision serious injuries and fatalities.

Acknowledgements

The authors would like to thank and acknowledge the assistance of Kosuke Mukaigawa, Kazuhiro Kubota and Jamie Mackenzie who assisted with the study. The Centre for Automotive Safety Research is supported by both the South Australian Department of Planning, Transport and Infrastructure and the South Australian Motor Accident Commission. The views expressed in this paper are those

of the authors and do not necessarily represent those of the University of Adelaide or Nihon University and their funding organisations.

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Contributed articles

Road Safety Policy & Practice

The Age of Light Vehicles Involved in Road Fatalities

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Key Findings

- Older light vehicles were over-represented in occupant fatality crashes over the period 2012 to 2016 in both Australia and New Zealand.
- The average age of light vehicles involved in occupant fatality crashes was found to be consistently above the average age of the registered vehicle fleet in Australia and the licensed vehicle fleet in New Zealand.
- Over the period analysed, the average age of the Australian registered vehicle fleet remained relatively consistent, however the average age of vehicles involved in occupant fatality crashes increased.

Abstract

Following a period of steady decline in national road tolls, recent consecutive increases in annual road fatalities in both Australia and New Zealand have caused community concern, with policy makers and road safety organisations working to ascertain reasons for this trend reversal. The Australasian New Car Assessment Program (ANCAP) sought to build a greater understanding of road crashes and potential causes for the recent trend reversal and began monitoring the age of light vehicles involved in road crashes where an occupant was fatally injured. The study used Australian and New Zealand crash data identifying the age of vehicles involved in road fatalities and compared the age distribution amongst those vehicles with the age distribution of vehicles in the registered / licensed vehicle fleets. The results found that older vehicles were consistently over-represented in occupant fatalities over the period 2012 to 2016 and that it is possible the average age of vehicles involved in occupant fatality crashes may be increasing.

Keywords

Vehicle age, occupant fatalities, light vehicles.

Introduction

Following a period of steady decline in national road tolls, recent consecutive increases in annual road fatalities in both Australia and New Zealand have caused community concern, with policy makers and road safety organisations working to ascertain reasons for this trend reversal.

The Australasian New Car Assessment Program (ANCAP) provides consumers with transparent advice and information on the level of occupant and pedestrian protection provided by different vehicle models in the most common types of crashes, as well as their ability - through technology - to avoid a crash. The program influences the design of new vehicles, encouraging vehicle manufacturers to offer a level of safety above that required by regulation and to continue to increase safety performance as technology develops.

It is well established that newer vehicles generally offer higher levels of safety when compared to older vehicles, due to technology developments and the inclusion of specific safety features, with studies based on real-world data supporting this (Hutchinson & Anderson, 2011; Newstead, Watson & Cameron, 2011). Statistical studies of real world crashes often report on factors such as driver age, crash type and posted speed limit, however the involvement of vehicle age in fatal crashes is less understood.

In an effort to build a greater understanding of the age of vehicles involved in crashes occurring in Australia and New Zealand, ANCAP began monitoring the age of light passenger and sports utility vehicles involved in fatal crashes, with the findings used to inform road safety policies and community education and advocacy activities. This paper sets out the findings over the analysed five-year period from 2012 to 2016.

Methods

Vehicle occupants represent the largest road user group in road fatalities each year, accounting for 66% of Australian road fatalities over the period 2012–2016 and 71% in New Zealand (Bureau of Infrastructure, Transport, and Regional Economics, 2018; New Zealand Ministry of Transport, 2017). Specifically, occupants of light passenger vehicles and sports utility vehicles (SUVs) represented approximately 49% and 56% of road fatalities in Australia and New Zealand respectively, while these vehicle types represented 75% and 78 % of the respective vehicle fleets (Australian Bureau of Statistics, 2017; New Zealand Ministry of Transport, 2018).

The study focusses on road fatalities where an occupant of a passenger car or SUV was fatally injured and compares the age distribution of those vehicles involved against the age distribution of the passenger car and SUV fleet. Other road user groups and vehicle types have not been included in the study. Australia and New Zealand have been analysed separately due to fleet profile differences and to provide information specific to each country.

To perform the analyses, two key datasets are required:

1. Road fatality data identifying the fatality type, vehicle type and year of manufacture; and
2. Fleet data identifying the type and age of vehicles within the registered (AUS) / licensed (NZ) fleet.

Focussing on occupant fatalities occurring in light passenger vehicles and SUVs resulted in datasets ranging from 500 to 700 fatalities each year in Australia and 120 to 180 fatalities in New Zealand. Organising this data by vehicle year of manufacture into groups matching the information

reported by the fleet statistical data allowed age comparisons to be made between vehicles involved in occupant fatalities and vehicles within the respective fleets.

The period between 2012 and 2016 represented the most recent five-year period for which detailed crash data was available for both Australia and New Zealand. This period formed the basis for the study.

Data Sources

Australian fleet information was sourced from the *Motor Vehicle Census, Australia* reports published by the Australian Bureau of Statistics (ABS), while New Zealand fleet information was sourced from the *New Zealand Vehicle Fleet Status* reports published by the New Zealand Ministry of Transport.

For Australia, Motor Vehicle Census reports are based on the fleet at 31 January of the report year. For the purpose of this study, fleet information at 31 January is considered a good representation of the fleet at the end of the previous year.

Vehicle age amongst the Australian passenger car and SUV fleet is reported in four groups based on year of manufacture. Three of these groups span five years each while the

remaining group includes vehicles that are fifteen years or older. These groups roll over based on the year in which the motor vehicle census is conducted.

For New Zealand, the fleet status data are reported at 31 December of the report year. Vehicle year of manufacture is generally reported in six groups, each spanning 10 years, however these groups do not rollover and remain consistent each year. As a result, the newest group identifying vehicles built between ‘2010-current’ continues to grow significantly with each status report as more new vehicles are added to the fleet.

Australian road fatality data identifying the fatality type, vehicle type and year of manufacture was sourced from the Bureau of Infrastructure, Transport and Regional Economics (BITRE) National Crash Database. Corresponding New Zealand data has been provided by the New Zealand Ministry of Transport and the New Zealand Transport Agency.

Results

Tables 1 and 2 show the age distribution amongst passenger vehicles and SUVs involved in occupant fatalities over the period 2012 to 2016. Vehicle age shown is based on the vehicle age in the year in which the crash occurred. Occupant fatalities where the vehicle year of manufacture is unknown represent 11% of the Australian dataset and less than 1% of the New Zealand dataset.

Vehicles aged 24 years or less were involved in the majority of occupant fatalities, with older vehicles, particularly those aged 30 years or older, involved in relatively few occupant fatalities. The average age of light passenger vehicles involved in occupant fatalities during the five-year period was found to be 12.7 years in Australia and 16.1 years in New Zealand.

The results comparing the age of vehicles involved in occupant fatalities and the age of vehicles within the fleet are shown separately for each year in Australia and New Zealand in Figures 1 and 2 below.

The results found that in Australia during 2016, vehicles built in 2012 or later represented the largest portion of registered vehicles at 31%, and were involved in the fewest occupant fatalities at 12%. Vehicles built between 2007 and 2011 represented 27% of registered vehicles and were involved in 13% of occupant fatalities. Vehicles built between 2002 and 2006 represented 22% of registered vehicles and were involved in 21% of occupant fatalities. The oldest group, those built in 2001 or earlier, represented the smallest portion of registered vehicles at 20% and held the largest share of occupant fatalities at 36%.

On average over the five-year period analysed, the newest vehicles aged up to four years in the year in which the crash occurred represented 31% of registered vehicles in Australia and were involved in 12% of occupant fatalities. The oldest age group, those vehicles aged 15 years or older, represented 20% of registered vehicles on average and were involved in 34% of occupant fatalities.

Table 1. Occupant fatalities by vehicle age at the time of crash (2012 to 2016)

Vehicle age (years)	Occupant fatalities in Australia	Percentage	Occupant fatalities in New Zealand	Percentage
0-4	361	12%	42	6%
5-9	554	18%	79	10%
10-14	745	25%	162	22%
15-19	638	21%	259	34%
20-24	297	10%	155	21%
25-29	62	2%	44	6%
30-34	25	1%	3	0%
35-39	4	0%	3	0%
40-44	3	0%	0	0%
45-49	5	0%	2	0%
50-54	1	0%	0	0%
55-59	1	0%	0	0%
60-64	2	0%	0	0%
65-69	0	0%	0	0%
70-74	0	0%	0	0%
75-79	0	0%	2	0%
80-84	1	0%	1	0%
Unknown	334	11%	1	0%
Total	3033	100%	753	100%

Table 2. Occupant fatality data key statistics (2012 to 2016)

	Average age (years)	Mode	Minimum age (years)	Maximum age (years)
Australia	12.7	14	0	83
New Zealand	16.1	18	0	83

For New Zealand in 2016, the results found that the newest vehicles built in 2010 or later represented 22% of licensed vehicles and were involved in 6% of occupant fatalities. Vehicles built between 2000 and 2009 represented 50% of licensed vehicles and were involved in 44% of occupant fatalities. Vehicles built from 1990 to 1999 represented 25% of licensed vehicles and were involved 45% of fatalities. Vehicles built prior to 1990 collectively represented 3% of licensed vehicles and were involved in 5% of occupant fatalities.

The New Zealand analysis shows relative consistency over the five-year period for vehicles built between 1990 and 2009. On average over the period, vehicles built between 1990 and 1999 represented 35% of licensed vehicles and were involved in 56% of occupant fatalities, while vehicles built between 2000 and 2009 represented 47% of licensed vehicles and were involved in 33% of occupant fatalities.

The differing age groupings reported by Australia and New Zealand, due to the reporting methods of the respective fleet statistics, make comparisons between the two datasets difficult. However, limited statistical datasets of the New Zealand fleet were available (New Zealand Ministry of Transport, 2018) allowing for some comparison to be made between the results. Figure 3 shows the age of vehicles involved in occupant fatalities in New Zealand during 2016 grouped into common age groups with the corresponding Australian results.

Figure 3 shows that in New Zealand during 2016, the oldest vehicles, built in 2001 or earlier, represented 40% of licensed vehicles and were involved in 60% of occupant fatalities. In contrast, the newest vehicles built in 2012 or later represented 15% of licensed vehicles and were involved in 5% of occupant fatalities.

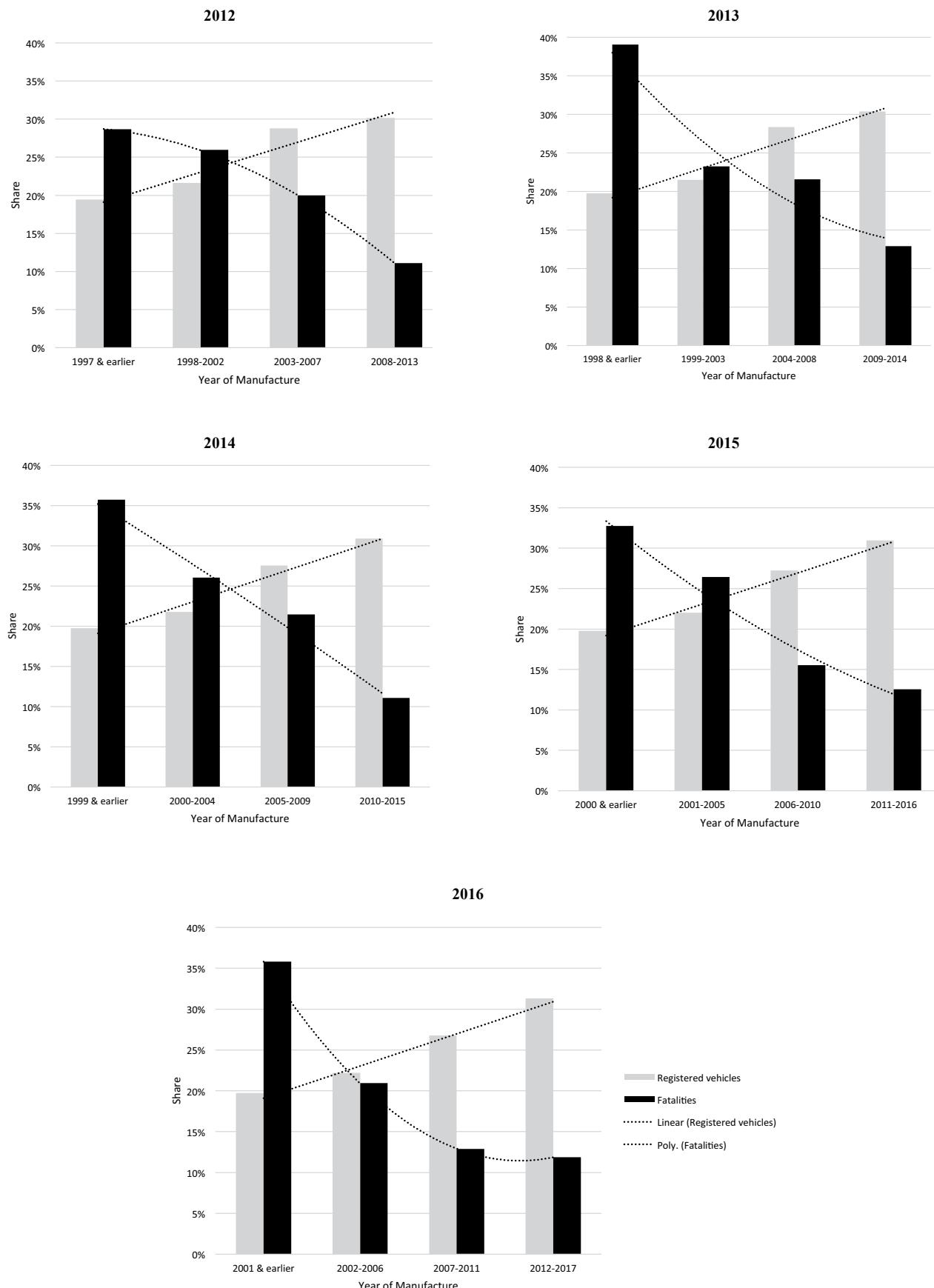


Figure 1. Age of vehicles involved in occupant fatalities vs age of registered vehicles (light passenger vehicles and SUVs) in Australia.

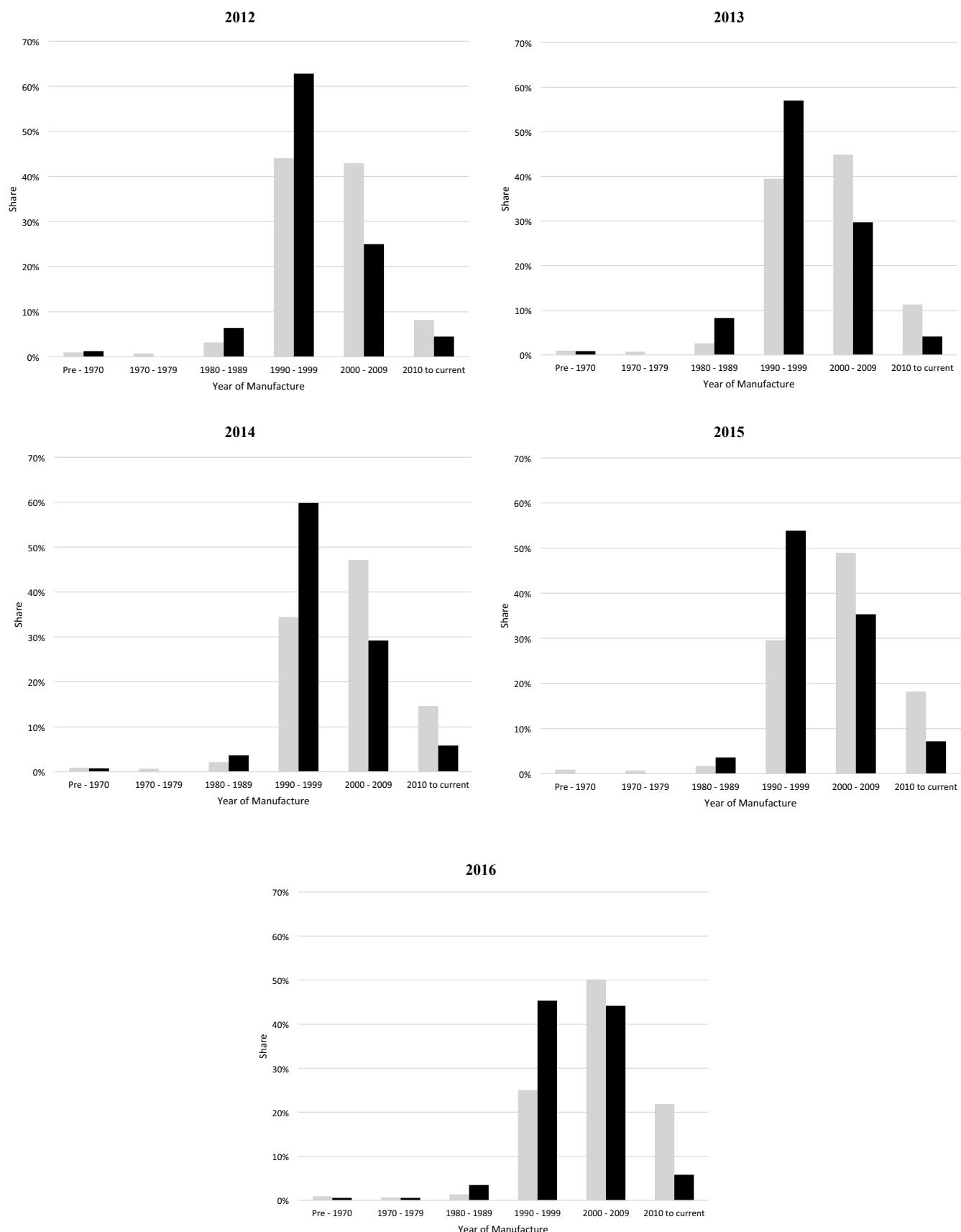


Figure 2. Age of vehicles involved in occupant fatalities vs age of licensed vehicles (light passenger vehicles and SUVs) in New Zealand.

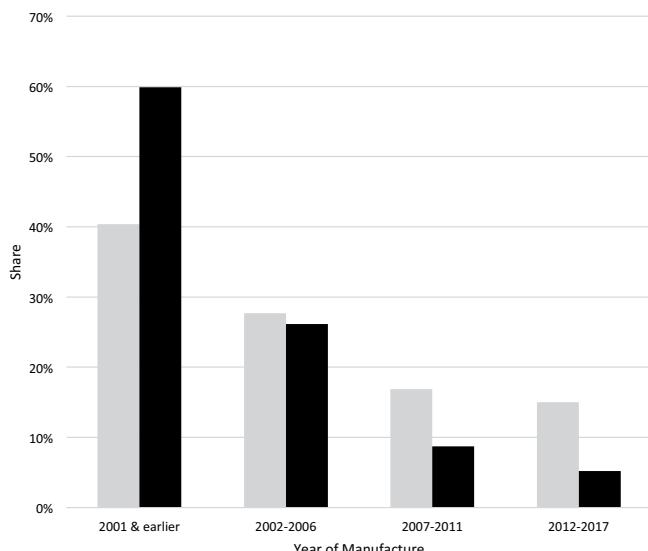


Figure 3. Age of vehicles involved in occupant fatalities vs age of licensed vehicles (passenger vehicles and SUVs) in New Zealand (2016).

Discussion

The results of the analysis show that older vehicles are consistently over-represented in occupant fatalities in both Australia and New Zealand over the period 2012 to 2016. Australian Motor Vehicle Census data consistently shows a relatively linear relationship between vehicle age and the share of the registered vehicle fleet over the five-year period, with fleet share decreasing with vehicle age. In contrast, the results suggest the relationship between vehicle age and involvement in occupant fatalities was the reverse, with crash involvement increasing with vehicle age. This relationship however is limited, as shown in Table 1, where vehicles aged 25 years and older were involved in few occupant fatality crashes.

Over the five-year period, the Australian results consistently showed that the oldest group of vehicles reported in the Motor Vehicle Census data represented the smallest portion of registered vehicles, yet were involved in the most occupant fatalities. Contrast to this, the newest vehicles

represented the largest portion of registered vehicles and were involved in the smallest portion of occupant fatalities.

The New Zealand results comparing the age distribution of vehicles involved in occupant fatalities and that of licensed vehicles presents differently due to the vehicle age groups provided in the New Zealand Fleet Statistics Reports. Vehicles built between 1990 and 1999 were consistently over-represented in occupant fatalities while vehicles built between 2000 and 2009 were consistently shown to be involved in less fatalities yet represented more of the licensed fleet. The portion of registered vehicles built in 2010 or later increased over time as expected, however the involvement in occupant fatalities for those vehicles remained relatively constant.

In comparing the vehicle age distribution between the Australian and New Zealand results, Figure 3 suggests a differing relationship between vehicle age and the distribution of licensed vehicles, with newer vehicles representing less of the fleet than older vehicles. However, the relationship between vehicle age and involvement in occupant fatalities does appear similar, increasing with age.

The observed difference between the Australian and New Zealand distribution of vehicle age amongst the fleet reflects the significant differences in the New Zealand fleet makeup, with used imports representing roughly 50% of the passenger vehicle and SUV fleet (New Zealand Ministry of Transport, 2017).

The average age of vehicles involved in occupant fatalities was shown to be consistently older than the average age of vehicles in the passenger vehicle and SUV fleet for both Australia and New Zealand, supporting the notion that older vehicles are over-represented in occupant fatality crashes.

In reviewing the average age results for each year over the five-year period, the results suggest a potential trend where the average age of vehicles involved in occupant fatalities is increasing. It is plausible that as newer vehicles become safer and therefore involved in fewer serious crashes, the share of serious crashes in which older vehicles are involved may increase. This does, however, imply that overall road fatality numbers will reduce. Further work is needed to establish whether a trend indeed exists or is emerging.

Table 3. Average age of vehicles involved in occupant fatalities.

	2012	2013	2014	2015	2016	2012-2016
Australia						
Fatalities	12.2 years	12.8 years	12.5 years	12.9 years	13.1 years	12.7 years
Registered vehicles	9.8 years					
New Zealand						
Fatalities	15.7 years	16.4 years	15.6 years	15.9 years	16.8 years	16.1 years
Licensed vehicles	14.0 years	14.2 years	14.2 years	14.3 years	14.4 years	14.2 years

Limitations

A key limitation to the findings is that the study does not investigate crash causation and factors contributing to the involvement of vehicles of various ages in fatal crashes. Driver demographics are considered a significant factor contributing to older vehicle involvement in serious crashes with many older vehicles involved in crashes being driven by more at-risk drivers, such as the young and inexperienced, and the elderly and frail (Transport for New South Wales, 2017).

The size of the dataset and statistical significance of the results, particularly New Zealand, also presents a limitation.

Conclusions

Investigating the involvement of vehicle age in fatal crashes and comparing the age distribution to that of the registered / licensed fleet, found that older vehicles aged between 15 and 25 years old

were consistently over-represented in road fatalities in which the occupant of a passenger vehicle or SUV was fatally injured over the period 2012 to 2016. Significantly older vehicles aged 30 years or more were not found to be significantly involved in occupant fatality crashes.

The average age of vehicles involved in occupant fatality crashes each year over the five-year period suggests a potential trend towards an increasing over-representation of older vehicles involved in occupant fatalities, which may be influenced by a reduced rate of fatality crashes involving newer vehicles.

Acknowledgements

The author would like to thank the Bureau of Infrastructure, Transport and Regional Economics (BITRE), the New Zealand Ministry of Transport and the New Zealand Transport Agency (NZTA) for their assistance in supplying the data for this analysis.

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Perspective on Road Safety

Safe Speeds Part 1: Political Decisions and the Limited Adoption of Speed Management for Road Safety

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Key Findings

- The global road safety crisis is deepening, and global targets for 2020 will not be met.
- Speed management is a critical lower cost solution with less delay to realisation of benefits than other elements of safe system management.
- Effective speed management is often resisted in make-or-break political decision making.

Keywords

Speed management, speed cameras, speed limits, communication, political decision making.

Introduction

The United Nations (UN) Global Plan for the Decade of Action (UNRSC, 2011) set a target of a 50% reduction in deaths by 2020 compared with the projected increase, and the UN Sustainable Development Goal (SDG) 3.6 is a 50% absolute reduction in both deaths and injuries by 2020. Based on performance to the end of 2016, neither target will be met. It is critical for global road safety that an SDG for road safety with a target date of 2030 be set, so that the now somewhat increased focus on the problem at the highest global levels (including the creation of the UN Fund for Road Safety in April 2018) is not lost.

Rather than decreases in deaths during the current decade, the global road safety crisis is deepening. The World Health Organization (WHO) recently released the estimate of global deaths (based on analysis which will be fully published late in 2018) at 1.34 million deaths in 2016, an increase on the 1.25 million in 2013 (WHO, 2015). Extrapolating this increase and cumulating the numbers reveal the alarming outcome that from 2018 to 2030 (when the anticipated next road safety decade will end) humanity will suffer 21.7 million deaths and 875 million injuries on the world's roads: the level of trauma of another world war. There have been many successes in road safety, yet effective road safety programs and policies have not been sufficient to mitigate the increases in motorization of most Low- and Middle-Income Countries (LMICs), which already suffer 90% of road crash deaths (WHO, 2015). In addition, many High-Income Countries (HICs) have retreated from sound road safety policies and programs, especially on speed management. These backward steps by HICs have the potential flow-on risk of delaying effective actions in LMICs which often adopt actions in HICs as models for success,

based on better road safety performance, more research to demonstrate effects, and HIC consultants' promotion of HIC policies.

This paper describes the limited extent to which effective evidence based speed management infrastructure, policies, and actions are adopted, and considers the central role of political decision making in this limited support for speed management to deliver road safety. This paper will be followed by a second paper addressing the question: Why has the road safety community met with such limited success in advancing automated speed enforcement, safe speed limits, and other speed management measures for road safety? The paper also offers suggestions to improve on this limited success.

Speed Management is Critical and Feasible

Speed is correctly recognised as a key factor in both crash occurrence and severity (Elvik, 2005; Job & Sakashita, 2016; Nilsson 2004), and thus the management of speed is central to the achievement of strong road safety improvements (GRSP, 2008; Job & Sakashita, 2016), as well as other benefits such as reducing climate change effects and harmful effects of noise from transport (Cameron, 2003; Sakashita & Job, 2016; Gomez et al., 2017). An extensive and irrefutable body of evidence exists showing that various means of reducing speeds have led to reductions in deaths and injuries and that allowing speeds to increase causes more deaths and injuries. Examples include speed management across the pillars of road safety, including reducing speed

limits (de Roos & Marsh, 2017; Graham & Sparkes, 2010; Sliogeris, 1992). The study by Sliogeris (1992) is especially compelling because it shows a marked increase in serious casualty crashes when a speed limit was increased by a political decision, and a marked reduction in these crashes when the speed limit was returned to its original lower level following the evidence for the clear harm resulting from the increase. Other effective examples include behaviour change through speed cameras and the promotion of enforcement (Li, El-Basyouny, Kim and Gargoum, 2017; for reviews, see: GRSP, 2008; Wilson, Willis, Hendrikz, Le Brocq, & Bellamy, 2010), vehicle based management of speed (**Carsten**, Fowkes, Lai, Chorlton, Jamson, Tate & Simpkin, 2008; Varhelyi, 2002), and road engineering to reduce speeds (Huang, Liu, Zhang, Wan, & Li, 2011; Makwasha and Turner, 2017; Mountain, Hirst, and Maher, 2005; Turner, Makwasha and Hiller, 2017).

Of these interventions, road infrastructure is the most directly sustainable, and strong speed enforcement is one of the most effective (GRSP, 2008; Wilson et al., 2010; including point-to-point or average speed cameras: Soole, Watson, Fleiter 2013; Montella, Imbriani, Marzano, & Mauriello, 2015) and least costly, in that cameras cost little, and generate income. This income can provide somewhat sustainable funding of road safety, though the income per camera hour reduces as drivers increase compliance with speed limits. The income generation as a side effect does create its own challenges such as raising accusations of revenue raising. These concerns have been toned down in some jurisdictions (including New South Wales and Western Australia) by hypothecating the camera revenue to road safety. In addition, support for speed management in the public arena from road safety experts can be helpful (e.g., Mooren & Grzebieta, 2010, 2011).

The World Bank and the Global Road Safety Facility (GRSF) aim to employ speed management opportunities through infrastructure or speed enforcement in projects. The GRSF is engaged in a Bloomberg Philanthropies funded program to improve road safety in 10 major cities around the globe, and this involves plans for speed management programs in many cities (reduced speed limits in Fortaleza and Addis Ababa, speed calming infrastructure in Bangkok; and raised platform crossings in Ho Chi Minh City as part of a Bus Rapid Transit project); a World Bank project planned for Rajasthan (India) includes speed humps to manage speeds on entry to villages and built up areas, and a project in Nicaragua includes plans for speed feedback and speed enforcement, as well as evaluation of the outcomes.

Political decisions and limited adoption of Speed Management

Decisions on speed management, especially on the adoption of and extent of automated enforcement, penalties for speeding, and other policies critical to efficacy (including the use of covert versus signposted enforcement) are political decisions. They are made by governments or ministers, and implemented through acts of parliament, regulations, and policy decisions by ministers and ministerial offices.

These decisions commonly are taken in the context of high-profile media and community commentary, and often are inconsistent with well-established evidence and expert advice (see Job, Sakashita, Mooren, Grzebieta, 2013; Mooren, Grzebieta & Job, 2013).

Despite their established efficacy and cost-effectiveness, speed cameras are generally not deployed or deployed to only a limited, sub-optimal extent in all countries and states. Speed cameras have even been abandoned or reduced in numbers in various countries and states (GRSP, 2008, p95). Limitations of use include: most countries have no point-to-point or average speed cameras despite their established efficacy; in various states of Australia, point-to-point cameras can be counted in single digits and some states do not have point-to-point cameras; and, in New South Wales (NSW) Australia, point-to-point cameras are only employed to enforce heavy vehicles not cars.

While New Zealand expanded its speed enforcement some years ago, point-to-point cameras were still under consideration by the Government in April 2018 (News Now, 2018). This indecision continues despite a 2011 report from the NZ Transport Agency showing their feasibility, reporting the evidence for their life saving results, and even identifying appropriate locations in New Zealand (Lynch, White and Napier, 2011). From 2014 to 2017 deaths in New Zealand rose 29.7% with Auckland suffering a 77.8% increase in deaths over the same period. Analysis has highlighted speed management as a core area of failure, with considered recommendations for increased penalties, more enforcement, and safer speed limits (Howard, 2018). The failure to address the speed issue reflects an over-focus on journey times (Wilson, 2018).

In Poland many speed cameras were switched off in recent years, and deaths increased; most states of the United States have no speed cameras, and they are explicitly prohibited in many states (e.g., Mississippi, Montana, New Jersey, Texas, and West Virginia). Despite the overwhelming evidence for savings of lives, injuries, environmental damage, economic costs, and fuel use at lower speeds (Cameron, 2003, 2012; Elvik, 2009; Hosseini, Kheyrbadi, Zolfaghari, 2015), highway and motorway speed limits in HICs are still well above ideal speeds for all these benefits. In addition, in many places speed limits have steadily risen despite being beyond the economically ideal speed. In Texas the maximum limit is now a whopping 85mph (137km/h) and six other states have maximum limits of 80mph, whereas all had a maximum limit of 55mph under earlier federal regulation (the Economist, 2018). European motorway speed limits are typically over 110km/h or in Germany some motorways have no limits, and in Australia's Northern Territory one road well below motorway standard had the speed limit removed. Increased speed limits led to a 15% increase in deaths in Israel (Richter, Barach, Friedman, Krikler, & Israeli, 2004), and in the USA have cost many thousands of deaths (Friedman, Hedeker, & Richter, 2009; Stuster et al., 1998). Most recently, in April 2018 India announced increases in speed limits on national roads.

With the important successful exception of the Australian state of Victoria, high enforcement tolerances on speeding, weak penalties for speeding, the absence of covert operation of speed cameras are still common in many countries and states despite their demonstrated value (Keall, Povey & Frith, 2001). These limited, delayed, and backward steps, along with slow or absent policy advance reveal broad, deep, deadly failures in public policy. Based on the key role of speed in crash causality and severity, the non-management of speed is a fundamental reason for the failure to deliver major improvements in global road safety.

No country on earth has even close to ideal speed management policy settings for evidence based best practice. Sweden, Netherlands, UK, and Switzerland are deservedly recognized as the best performing countries in road safety, and all have strong speed management as a core mechanism of success. However, even these countries have actively sub-optimal speed management policies. Every country could use many more engineering features to manage speed (raised platform crossings, speed humps, well-designed roundabouts), and many more speed cameras and point-to-point systems than are in use. Toll booth entry and exit records include (or are readily able to include) time, and can thus be employed as point-to-point enforcement,



Figure 1. 20km/h speed limits in Switzerland are accompanied by appropriate engineering of the road.

yet this opportunity is ubiquitously ignored. Sweden places limits on the total fine revenue of cameras and so does not proceed with many detected offences, and could effectively deploy many more cameras. Switzerland has introduced low residential speed limits (20km/h) with effective speed managing road infrastructure in some locations (Figure 1), but has high speed limits on expressways, and sub-optimal automated and police enforcement of speeding. The Netherlands has been a leader on speed enforcement, yet motorway speed limits were raised from an already sub-optimal 120km/h to 130km/h (Dutch News, 2013).

Finally, no country has developed and effectively implemented available technological advances (such as strong speed enforcement via GPS tracking of all vehicles) or even technologies available for many years to manage

speeds through vehicles (such as simple speed limiting to the maximum open road speed for all vehicles). The further technological step of GPS based speed limiting (the speed limiting version of Intelligent Speed Adaptation, ISA) is also available, but not adopted. One argument against speed limiting of vehicles is that speed limiters could sometimes cause crashes, in cases where speed is required to avoid the crash. The scenarios in which this could occur are hypothetical and rare (though possible) compared with the huge numbers of deaths from speed which would be avoided if speeding were to be prevented by the vehicle. On balance the safety benefits will be profound.

The alternative to speed limiting sometimes proposed is to allow an over-ride on ISA, or to require Speed Assistance Systems (SAS) which warn the driver regarding speeding. Speed limiting systems generate much greater safety benefits than speed warning systems (Carsten et al., 2002), though SAS may be the first step in the process of full development. The Australian New Car Assessment Program will award extra safety ratings for cars with SAS, and in May 2018 the European Parliament proposed making SAS mandatory (ETSC, 2018). Thus, there are important steps being taken in relation to the role of the vehicle in speed management.

Conclusions

The UN targets for the Decade of Action and the road safety goals in the SDGs will not be met. This should spur more, and more effective actions rather than apathy and retreat. In addition to increased action in the remaining years of the current decade, another target for road safety is critical for the next decade at global, regional, national, and sub-national levels. An extensive body of evidence exists on how to achieve the goals, and one of, if not the, most cost-effective mechanisms for improving road safety is effective speed management. It should have a fundamental role in planning for the future of road safety, including in the strategic plans for another decade.

The limited actions and backward steps reviewed above are the result of political decisions which determine relevant laws, regulations, policies, and practices. Minimal steps forward, backward decisions and deliberate inaction on speed management are often made in opposition to the evidence and expert road safety advice. These decisions by many high income jurisdictions not only reduce road safety within the jurisdictions but also risk slowing road safety actions in the LMICs, which already suffer 90% of global road crash deaths (WHO, 2015). Reasons for these political decisions, and recommendations for addressing them, are offered in a follow-up paper.

Acknowledgements

The GRSF acknowledges past and current donors including Bloomberg Philanthropies, CITA, DFAT Australia, the FIA Foundation, the Government of the Netherlands, SIDA Sweden, U.K. Aid (DFID), and the World Bank's Development Grant Facility. Road Safety research by the staff of GRSF is also directly supported by the World Bank.

This paper was improved by suggestions from Dipan Bose, Marc Shotten, and Chika Sakashita. The views and opinions expressed do not necessarily represent those of the World Bank.

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

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SMART CUSHION AUSTRALIAN 2 YEAR IN-SERVICE PERFORMANCE REPORT

Smart Cushion Replacement Parts Costs

- 3 main types of components were replaced over the 59 resets
- Shear Pins ($2 \times \$2 = \4) required for every reset
- Delineator Panel (\$190) required for 21 resets
- Sled Panel (\$1416) required for 4 resets
- The **total cost** of replacement parts over the **59 resets was \$9,994**
- The **average cost** for each reset was **\$169**

Durability and Robustness

- 31 different Smart Cushion units required 1 or more resets
- 8 Smart Cushions were reset twice
- 2 Smart Cushions were reset 4 times
- 1 Smart Cushion was reset 5 times
- **1 Smart Cushion was reset 11 times**
- Average Reset Time **55 Minutes** (1 person crew)
- **All Smart Cushions were reset fit for service after an impact**

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