Vol 29 No 2, 2018

Journal of the Australasian College of Road Safety

Formerly RoadWise – Australia's First Road Safety Journal

Peer-reviewed papers

Contributed articles

Road Safety Plan 2021

Taking action to save lives on NSW roads

LIVES LOST IN 1970
1310

LIVES LOST IN 2017
392

STATE PRIORITY TARGET
LIVES LOST IN 2021
287
OR FEWER

2056 VISION
0

The Road Safety Plan 2021 was released in February 2018. It features targeted and proven initiatives that will help us progress towards our goals and address key trauma trends on NSW roads.

The NSW Government will deliver targeted actions across six priority areas in the Plan, alongside continued delivery of existing road safety initiatives. Achieving our aspirational goal of moving Towards Zero trauma will require ongoing collaboration, including with road safety researchers, advocates and every member of the community.

Building a safe future

As the NSW population, road network and trips continue to grow, we have the opportunity to make sure the latest proven safety features are designed into our transport system.

Looking to the future, it will be important that research evidence supports the integration of safety features and new technologies into our road networks to improve safety.

Smarter and integrated planning can prevent crashes from occurring. If a mistake happens, better road design can mean that the impact of the crash doesn't result in death or serious injury.

A strong evidence base

Ensuring we have a strong research agenda will see that road safety professionals have detailed understanding of lifesaving vehicle safety features and equipment, innovative road design and roadside safety features and the motivations behind unsafe driving behaviour.

The Plan outlines the need for a continued robust research program that includes:

- Research into connected and emerging vehicle and infrastructure technology.
- Continued research to support behavioural and policy reform for key priority areas.
- Trials of new and promising road and roadside safety products, and reviews of innovative road design approaches and safety programs internationally.
- Program evaluation research to improve how we implement programs.
- Safe system analysis of serious crashes to help us understand all the reasons why they have occurred and how our systems can prevent them in the future.
- Continuing to enhance data collection and information systems.

NSW GOVERNMENT

Find out more at towardszero.nsw.gov.au/roadsafetyplan

TOWARDS ZERO

REGISTRATION NOW OPEN

MARK YOUR DIARY WITH THESE KEY DATES:

Early Bird Registration Deadline: **1 June 2018**

AUSTRALASIAN ROAD SAFETY CONFERENCE 2018

International Convention Centre Sydney
3–5 October 2018

FOUNDING PARTNERS

Australasian College of Road Safety

Austroads

PLATINUM SPONSOR

NSW Government

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?

ARSC2018 is expected to attract 500-700 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.

REGISTRATION NOW OPEN

EARLYBIRD REGISTRATIONS CLOSE 1 JUNE 2018

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**.

YOUR HOST CITY: SYDNEY

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

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3M-ACRS Diamond Road Safety Award. Since 2011.

Submit your Road Safety Program for a chance to **Win a trip to the USA!**

Enter & Get Recognised!
Have you or a colleague recently developed a road safety treatment/initiative that stands out beyond traditional activities and delivered improved road safety? You could be the winner! We are looking for entries from any road safety practitioner who works within the Australasian private or public sector. Don't miss out on your chance to win and be recognised!
The individual team leader from the winning project will receive a trip to the USA to attend the 49th ATSSA annual convention and also visit 3M head office in Minnesota.

Who will judge entries?
All entries will be judged by an independent committee of industry representatives, established by the ACRS.

3M-ACRS Diamond Road Safety Award 2018

To enter & more information, visit theaustralasianroadsafetyawards.com.au
Entries open 1st March 2018 and close 5pm (EST), 15th July 2018

Australasian College of Road Safety

Nominations now open!

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Cover image

In desert environments such as in Africa, the Middle East and Asia, roadside structures such as road safety barriers can cause sand accumulation on the roadway (top photo), leading to serious loss-of-control and run-off-road crashes. See *Original Road Safety Research* article (Marsh and Webster (2018). Mitigating localised sand accumulation using wire rope safety barrier. *Journal of the Australasian College of Road Safety*, 29(2), pages 20-26) showing two-row wire rope safety barriers allowing sand to flow without sand accumulation on the roadway (bottom photo).

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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/

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Editorial Board

From the President

Dear ACRS members,

In the last Issue of our Journal, I suggested we needed to recognise the "disruption" that new technology was having on the communication of research results, and the challenge in being innovative with our messages to ensure they are heard and understood.

This Issue has a wide range of papers which cover a wide range of critical road safety topics from speed management, road infrastructure management, motorcycle safety, bicycle safety, vehicle safety management, to road user behaviour management, reflecting the breadth of expertise coverage of the College.

These varied papers make up what may be called the "silos" of road safety, but are vital to solving specific problems or to being a building block for further research to help find better ways to reduce road trauma.

There is always the risk of being caught up in the "silo" and not looking out to see how each specific work can contribute to the bigger picture. We need to be able to communicate both and ensure that that communication is innovative and effective to implement the many solutions needed in our quest to implement Vision Zero.

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, Victoria, Queensland and NSW.

Australian Capital Territory (ACT) and Region

2017 ACT Road Safety Forum: Achieving Safe Systems for ACT Roads

The Chapter's involvement in the Forum has been completed. A report on it has been completed and forwarded to the ACT Justice and Community Safety Directorate.

2018 Program

The Chapter committee met in February to consider its program for 2018. It agreed to continue its policy of working closely with stakeholders on issues where important road safety outcomes may be achieved through the sharing of information between a range of concerned parties. The following projects have been nominated for action:

Graduated Licensing Forum, May-June 2018

This Forum will be undertaken for JACS as part of the consultation process associated with a current Government review of the ACT Graduated licensing system.

The Forum will attempt to consider responses currently being sought from the community and provide advice to JACS on the responses and issues raised.

Sharing the roads with vulnerable road users on rural roads in ACT and surrounding NSW, August-September 2018

ACT residents are increasingly using NSW rural roads in surrounding areas individually or in small or larger groups for recreational riding on motorcycles or bicycles. Often they have to share the roads with commercial as well as private vehicles on roads of varying nature. Safety concerns exist about the mix of this traffic on certain roads.

The purpose of the forum will be to identify the issues and the range of actions that may be available to minimise risks to vulnerable road users and to ensure local residents and businesses have reasonable access to their roadways.

This project will be undertaken in close cooperation with road safety authorities in the ACT and surrounding NSW. Representative of other interested user groups and interested parties will be invited to participate actively.

Wildlife crashes in ACT and surrounding area, late 2018-early 2019

Crashes between motorists & motorcyclists are a matter of concern for some time in the ACT and surrounding rural areas of New South Wales. Discussions have taken place between the Chapter, the Royal Australasian College surgeons and ACT Health. This project, and its timing, will depend on continuing discussions and other possible stakeholders in coming months. The objective will be to assess whether further cost effective initiatives could be identified and implemented to assist in reducing serious injury actions of this crash type.

Automated Vehicles - Benefits and challenges, To be advised

This forum would be developed to have a wide appeal to the general public. It would provide a broad realistic introduction to the use of automated vehicles in Australia. Safety benefits and structural, industry/government & legal communication inhibitors will be discussed.

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

Victoria (VIC)

Firstly, I would like to sincerely thank David Healy and Marilyn Johnson for acting in the role of Chapter Chair while I have been on maternity leave. Since returning to the position of Chair in late 2017, the Victorian Chapter Committee have held discussions on the role of the chapter, and how we could better support and engage with our members. It was decided to conduct a short online survey of Victorian members to help inform these discussions, of which we received 41 responses.

The results showed that 68% (n=28) of participants had attended an ACRS Victorian Chapter seminar, and over 80% of participants rated this as either good or excellent. Thirty two percent (n=13) of participants had not attended a seminar, with the top reasons for not attending including presentations being at an inconvenient time (38%, n=5) and location (38%, n=5). All respondents were asked to rate their interest in potential future activities and a high percentage reported that they would be extremely or very interested in a joint seminar between ACRS Vic and another road safety institution (47%, n=19), a networking night (37%, n=15), or an online seminar (35%, n=14). Forty percent of respondents currently had limited to no involvement with the ACRS Vic

Chapter (n=16), 40% had some involvement, while 20% were regularly or very involved (n=8). Participants were divided in their satisfaction with their current involvement, with 50% satisfied (n=20) and 46% hoping to change their involvement (n=19). Overall, respondents appeared to regard the ACRS Victorian Chapter highly, with most reporting that they were somewhat or very satisfied with the chapter (52%, n=21), and the rest reporting that they were neither satisfied nor dissatisfied (47%, n=19). These results have helped the committee with future planning and will guide our activities moving forward.

The Chapter is planning to cross-promote a cycling seminar being held by Monash University in June and has commenced planning for a seminar in August on drink and drug driving.

VIC Chapter Chair
Melinda Spiteri

Queensland (QLD)

SEMINARS

6th March 2018 – Dr Chris Cherry, University of Tennessee: ***New Probe Data Sources to Measure Cycling Behavior and Safety***

Dr Chris Cherry is an Associate Professor at the University of Tennessee. His research interests include bicycle and pedestrian safety and system design, the role of e-bikes in the transportation system, multimodal transportation planning and economics, travel behaviour and demand, sustainable transportation and transit security. He is currently visiting the University of Queensland.

Dr Cherry's presentation focused on emerging probe data sources from smartphones and on-board devices, which are able to measure behaviour of cyclists with very high resolution. From this, for the first time, we can measure relatively precise behaviour that allows new insights into exposure, route choice, safety behaviour, or technology choice. Probe data, merged with other data sources, can begin to develop a more complete picture of cyclists' on-road behaviour. The presentation demonstrated examples of analyses done to investigate cyclist behaviour using app-based and on-board GPS data in the context of individual cyclist behaviour (i.e. app users) and behaviour of bikeshare users (i.e. on-board GPS fleet tracking devices). The applications cover route choice, travel patterns, surrogate safety behaviours like wrong-way riding, and enabled comparison of differences between conventional- and electric-bike users.

5th June 2018 - "Demolishing the Silos": Workshop on the Safe System Approach

The Queensland Chapter will be holding a workshop on the Safe System Approach titled "Demolishing the Silos". This will be held at QUT, Gardens Point in the OJW Room.

The workshop will be followed by the Chapter AGM.

QLD Chapter Chair
Dr Mark King

New South Wales (NSW)

The NSW Chapter has been seeking to increase the profile of road safety and the role and support of the Chapter with key stakeholders and across the community. This has seen the Chapter engage with the Office of the NSW Minister for Roads via a meeting with the Minister's advisor on road safety and engaging in interviews with 2GB's Michael McLaren on topical road safety issues including the release of the NSW Road Safety Plan and the hazard of mobile phone use by drivers.

With the funding support from the NSW Centre for Road Safety via its community grants program, the Chapter is also continuing to plan and deliver seminars to College members during 2018. With this the Chapter is ensuring as wide a coverage as possible to members in regional NSW by making all seminars, and the Chapter's Annual General Meeting, available as live and interactive webinars.

All NSW Chapter Members are encouraged to keep an eye on the College Newsletter and the Chapter page on the College website for information about upcoming events and how they may participate in Chapter activities.

NSW Chapter Representative
Mr David McTiernan

ACRS News

ARSC2018: Wow! Thanks for the Huge Number of Submissions! It's Already a Record-Breaking Event!

The ARSC2018 Scientific sub-Committee bringing you ARSC2018 has been absolutely delighted with the EXCEPTIONAL RESPONSE to the ARSC2018 Call for Abstracts.

Thank you so much to everyone in the road safety community who is engaging with ARSC2018, an event which promises to be our largest-ever - VERY EXCITING!

We are delighted to announce that we've received:

- 250+ Abstract Submissions
- 20+ Symposium Proposals - each being 90 minutes in duration

With a theme of "Towards Zero: Making it Happen!", ARSC2018 will showcase the regions' 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 brings with it a special focus on engaging all levels of government and community, from the city to the bush, to move Towards Zero. The comprehensive 3-day scientific program will showcase the latest:

- Research;
- Education;
- Policing programs;
- Policies and management strategies;
- Technological developments in the field;
- National and international keynote speakers;
- Oral and poster presentations;
- Expansive stakeholder exhibition; and
- Workshops and interactive symposia.

Thanks to the many authors keen to share their research, programs, expertise and advice with an anticipated audience of 700+ road safety stakeholders. Together with a diverse group of Conference Editors and Peer-Reviewers, the ARSC2018 Scientific sub-Committee is already moving forward with the peer-review process to ensure we bring you **the best of the best Papers, Presentations, Posters, Workshops, Symposia, Keynotes and Plenary Panel Sessions.**

Our expansive and expertise-driven ARSC2018 team continues to be committed to working collaboratively with all stakeholders, and includes many, many organisations who generously provide their time to ensure the best outcome from this prestigious event - the outcome we all strive for -> Towards ZERO - Making it Happen!:

- Founding Partners ACRS and Austroads
- Platinum Sponsor Transport for NSW
- The ARSC2018 Committees:
- ARSC2018 Organising Committee
  * 27 members across 20+ organisations *
- ARSC2018 Scientific sub-Committee
  * 26 members across 20+ organisations *
- ARSC2018 Conference Editors
  * 45 members across 40+ organisations *
- ARSC2018 Peer-reviewers
  * 200+ members across hundreds of organisations*
- ARSC2018 International sub-Committee
  * 11 members from across the globe *
- ARSC2018 Social sub-Committee
- Gala Dinner and Awards Sponsor - Transurban
- Our many other early sponsors, exhibitors and supporters
- Our dedicated team of Event Managers from Encanta

And a HUGE THANKS to our ARSC2018....

* Authors *

* Presenters *

* Poster Contributors *

* Symposium Organisers *

* Workshop Organisers *

* Keynote & Plenary Panel Speakers *

* Delegates *

We look forward to working with you!

Thank you to every organisation who has taken up early partnerships with the conference this year - without you the conference would not be shaping up to be such a successful event, able to save more lives and injuries on our roads:

- Platinum Sponsor - NSW Government
- Dinner & Scientific Awards Sponsor - Transurban
- Conference App Sponsor - Austroads
- Lanyard and Namebadge Sponsor - Monash University Accident Research Centre (MUARC)
- Exhibitor - SydneyDPS
- Exhibitor - MetroCount
- Exhibitor - Centre for Road Safety and Accident Research Queensland (CARRS-Q)
- Exhibitor - Forum 8;
- Workplace Safety Award Sponsor - National Road Safety Partnership Program (NRSPP/ARRB)
- Supporter - Transport & Road Safety Research @ UNSW (TARS)
- Supporter - Highway Engineering Australia,
- Supporter - Safety Journal
- Supporter - Roads & Infrastructure Australia
- ARSC2018 co-Hosts - Austroads, ACRS, ARRB

Ministerial Inquiry into The National Road Safety Strategy 2011-2020

Last September saw the announcement of a Ministerial Inquiry into making the National Road Safety Strategy more effective.
The following ACRS members constitute the Inquiry Panel, and we look forward to their report:

- **Inquiry Co-Chair- Associate Professor Jeremy Woolley**, Director, Centre for Automotive Safety Research, University of Adelaide - ACRS SA Chapter Chair
- **Inquiry Co-Chair - Dr John Crozier** - Chair, Royal Australasian College of Surgeons Trauma Committee - ACRS member
- **Inquiry Principal Advisor - Mr Rob McInerney, CEO**, International Road Assessment Program - ACRS Fellow
- **Inquiry Principal Advisor - Mr Lauchlan McIntosh**, President ACRS, Chair, Global New Car Assessment Program - ACRS Fellow

Mr Lauchlan McIntosh AM FACRS with Deputy Prime Minister Hon Michael McCormack MP

Deputy Prime Minister Hon Michael McCormack MP Emphasises: 'I Am Passionate and Committed to Work with the Australasian College of Road Safety Towards Zero Deaths'

The College President, Lauchlan McIntosh AM, and CEO Claire Howe, were fortunate to meet with the recently inaugurated Deputy Prime Minister (and Minister for Infrastructure and Transport), Hon Michael McCormack MP.

The College has been fortunate to have developed a strong relationship with Minister McCormack over many years due to his involvement and commitment to road trauma reduction. Minister McCormack yesterday reiterated his passion and commitment to working with all stakeholders towards our ultimate target of zero deaths.

Tuesday 20 March 2018

Issues discussed during yesterday's meeting included the following:

- Congratulating Minister McCormack on his elevation to the position of Deputy Prime Minister
- Concern over current trauma rates - deaths and serious injuries
- Ministerial Inquiry into the Effectiveness of the National Road Safety Strategy
- ACRS pre-Budget Submission
- ARSC2018 - Minister McCormack's participation, as well as the participation of the federal govenment department of Infrastructure, Regional Development and Cities

We look forward to the participation of Minister McCormack at ARSC2018, in particular during the RSC2018 Conference Dinner and Awards Ceremony to reward our outstanding road safety advocates and achievements.

MEMBER NEWS: Austroads Report - Towards Safe System Infrastructure - A Compendium of Current Knowledge

Austroads has released a report that provides a compendium of knowledge on Safe System treatments and identifies real world experience in the practical application of solutions that can mitigate crash severity.

The Safe System is internationally regarded as the best practice approach to road safety. Although Australia and New Zealand have been early adopters of the approach since 2004, there has been a lack of clarity amongst practitioners on how best to integrate the approach into their daily activities.

Assessment frameworks and tools are now emerging that allow the alignment with Safe System be better quantified. This report presents a hierarchy of treatments that provide practitioners with a basic understanding of the types of practices that should now be applied on a trajectory towards a Safe System. Primary treatments are capable of virtually eliminating death and injury and certain supporting treatments can transform the network a step closer to reducing the overall harm being caused.

The report brings together the principles, theory and rationale behind the Safe System along with established examples of real world implementations. The document summarises and highlights the state of knowledge of speed management, median treatments, roadsides design and management (clear zones versus barriers), intersection issues, vulnerable road user issues, motorcycle and heavy vehicle safety. The ongoing development of assessment tools is also discussed.

MEMBER NEWS: Future Transport 2056 - We Are Live! (From Clare Gardiner-Barnes - Transport for NSW Via Linkedin)

Future Transport 2056, we are live! As Jim Betts states in this video "I have never seen collaboration on this scale between government agencies" and I couldn't agree more. Together, Transport for NSW, Infrastructure NSW and the Greater Sydney Commission have developed and released plans that will deliver outcomes for NSW. Thank you to Jim, Sarah Hill and their teams for collaborating and integrating our planning for customers. As I say in the video, I am excited to see what it all looks like! Thank you to my team for your efforts and dedication to this game-changing project, I am very proud!

In-vehicle collision avoidance technology (CAT) has the potential to prevent crash involvement. In 2015, Transport for New South Wales undertook a trial of a Mobileye 560 CAT system that was installed in 34 government fleet vehicles for a period of seven months. The system provided headway monitoring, lane departure, forward collision and pedestrian collision warnings, using audio and visual alerts.

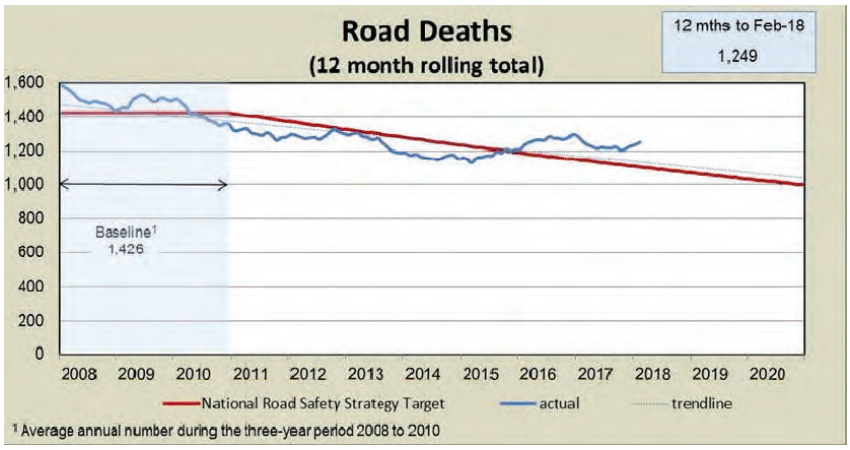
MEMBER NEWS: News from the Canberra Media Launch of the Naturalistic Truck Safety Study

ACRS President & CEO, Mr Lauchlan McIntosh and Ms Claire Howe, were invited to attend the launch of the Naturalistic Truck Safety Study last week at the Queen Victoria Terrace in Canberra, between Old Parliament House and new Parliament House. This launch is the result of a successful partnership between Seeing Machines, Monash University Accident Research Centre (MUARC), Ron Finemore Transport and Volvo Trucks Australia. The launch included speeches from all partners as well as the Minister for Urban Infrastructure and Cities, Hon Paul Fletcher MP.

The Advanced Safe Truck Concept represents the first industry led Cooperative Research Centre Program grant studying heavy vehicle behaviour in Australia and is the first world-wide study to be done using driver monitoring technology. This important two-phase program will test car an truck drivers in MUARC's Advanced Driving Simularo, including Australia's first research truck simulator, and in a naturalistic on-road study in the Ron Finemore Transport fleet.

MEMBER NEWS: Federal Department Releases Updated National Road Safety Strategy Actual vs Target Statistics

Australia's Department of Infrastructure, Regional Development and Cities has recently released updated charts and figures detailing Australia's progress against the 30% reduction of death and injury targets outlined in our National Road Safety Strategy 2011-2020.



United Nations General Assembly adopts a UN Resolution "Improving global road safety" and the UN Road Safety Trust Fund is launched, followed by the 25th UN Road Safety Collaboration meeting

The 25th United Nations Road Safety Collaboration (UNRSC) meeting held on 12-13th April 2018 at the United Nations Headquarters, New York, USA was the first meeting since the Australasian College of Road Safety (ACRS) became a UNRSC member at the last meeting in March 2017. UNRSC members are required to self-fund to participate in the UNRSC meetings. Our Journal Managing Editor and ACRS member, Dr Chika Sakashita, has been the focal person for the UNRSC and Chika funded her attendance at the UNRSC meetings as the ACRS Representative without any expenses incurred by the ACRS. Chika reports on the UNGA adoption of the resolution on improving global road safety, the launch of the UN Road Safety Trust Fund, and the 25th UNRSC meeting.

UNGA Adoption of Resolution "Improving global road safety"

The General Assembly adopted a resolution entitled "Improving global road safety" (document A/72/L.48) in the morning of Thursday, 12th April 2018 at the United Nations in New York. The Russian Federation introduced the draft text. Monaco, Luxembourg, Sweden, United Kingdom, Oman, Australia, Republic of Moldova, Armenia, Philippines, Brazil, Czech Republic, Nepal, Spain, United Republic of Tanzania, Turkmenistan, Kyrgyzstan, Afghanistan, Uruguay, Honduras and Belarus, as well as the European Union and the International Federation of Red Cross and Red Crescent Societies made statements in support of the draft resolution.

Llew O'Brien MP represented Australia (photo 1) and noted that since co-sponsoring the resolution that had established the Decade of Action in 2011, Australia had supported global efforts to address road safety and was pleased to sponsor the current draft resolution on improving global road safety. He also noted that Australia had adopted a safe system approach to road safety and was willing to share its experience, as well as learn from others. Llew O'Brien MP also welcomed the inclusion of specific road safety targets in the Sustainable Development Goals and recognized the importance of setting ambitious targets to reduce deaths and injuries from road crashes.

Launch of the UN Road Safety Trust Fund

Following the UNGA adoption of the resolution, the United Nations Road Safety Trust Fund was launched at the UN Headquarters in New York in the early afternoon of Thursday, 12th April 2018. The UNECE will host the Secretariat of the United Nations Road Safety Trust Fund and the Administrative Agent is the United Nations Multi-Partner Trust Fund Office based at UNDP. The Advisory Board will provide strategic direction to the Fund, including advice on criteria for proposals, monitoring and evaluation, on priorities of funding projects, on organizational structure and consultations. The World Bank, as the host of the Global Road Safety Facility, and the World Health Organization are members of the Advisory Board. The Steering Committee will have the direct oversight on the Fund and the authority to make decisions including the approval of the projects for funding.

The Fund will support concrete actions aligned with the five pillars of the Global Plan for the Decade of Action for Road Safety:

1. Strengthened road safety management capacities
2. Improved safety of road infrastructure and broader transport networks
3. Enhanced safety of vehicles
4. Improved behaviour of road users
5. Improved post-crash care.

Amina Mohammed, United Nations Deputy Secretary-General, (photo 2) welcomed the launch of the United Nations Road Safety Trust Fund and thanked all

Photo 1: Llew O'Brien MP (co-Chair, Parliamentary Friends of Road Safety - Australia) representing Australia in support of Resolution "Improving global road safety" at the UN General Assembly, New York, USA

Photo 2: Amina Mohammed, United Nations Deputy Secretary-General, welcoming the United Nations Road Safety Trust Fund at its launch at UN Headquarters, New York, USA

Photo 3: HRH Prince Michael of Kent opening the 25th United Nations Road Safety Collaboration (UNRSC) meeting at the United Nations Headquarters, New York, USA

stakeholders for their support, including private-sector entities that had pledged contributions towards the Fund.

Jean Todt, the United Nations Secretary-General's Special Envoy for Road Safety, identified that the UN Road Safety Trust Fund will help mobilise and unlock financial and technical resources in order to strengthen the capacity of government agencies, local governments and city authorities to develop and implement road safety programmes, especially in low and middle-income countries and called on all stakeholders, United Nations Member States, and partners to contribute to the Fund.

Pledges to contribute as founding donors were made at the Fund's launch by the FIA Foundation, and two members of the FIA High Level Panel for Road Safety, Total and 3M. The FIA Foundation contributed $10 million to the Fund and Saul Billingsley, Executive Director of the FIA Foundation, said "The launch of this first ever United Nations Fund for global road safety is an important recognition that our collective efforts to tackle road safety must be scaled up. Governments have provided the mandate for action, but not yet the resources to deliver it. We urgently need a massive increase in funding, commensurate to the scale of the problem", and called on others to step up with financial contributions.

25th UNRSC meeting

The meeting was opened by HRH Prince Michael of Kent (photo 3). The Prince noted the UNRSC meetings to be almost like an alumni of Prince Micheal Interantional Road Safety Awards and hoped the UNRSC efforts as well as the third Global High-Level Conference on Road Safety hosted by Sweden would lead to a new level of commitment to road safety action.

Key outcomes of the 25th UNRSC meetings include:

1. Barry Sheerman MP as the Chairman of the Leadership Council introduced the Global Network for Road Safety Legislators established at an international meeting of Parliamentarians in London in December 2016. The Manifesto #4RoadSafety includes ten key recommendations for Parlimentarians worldwide including the implementation of interventions receommended in the SAVE LIVES package. Parliamentarians worldwide can register their support by filling in the form.
2. Sweden will hold the 3rd Global High-level Conference on Road Safety in 2020 to prepare a forward-looking declaration leading up to 2030. UNRSC members contributed to the themes and focus of the High-level Conference and agreed that each member should encourage Parliamentary leaders from their countries to join the Conference in Sweden.
3. The themes, focus and timing for the 5th UN Global Road Safety Week were discussed. Leadership was proposed to be the underlying thread of the Week reflecting Sweden's visionary leadership in road safety in Vision Zero as a way to create a momentum for the High-level Conference in Sweden in 2020 and draw the much needed attention and commitments from leaders worldwide to act on evidence-based road safety interventions. UNRSC members will continue to contribute to the development of the theme and logistics such as phrases and name of the Week.
4. The 12 voluntary Global Road Safety Performance Targets for road safety and a set of related indicators aligned with the 2030 SDG targets were introduced as a result of the Informal Conslutation of Member States in February 2018. UNRSC members contributed to the development of these targets, with Who thanking the UNECE, the World Bank, and others for expert input.

Chika made a partner report to the UNRSC on the Journal of the Australasian College of Road Safety (JACRS) Special Issue on Speed Management published in May 2017 in support of the UN Global Road Safety Week May 2017. Chika also invited all UNRSC members to attend the 2018 Australasian Road Safety Conference in Sydney, Australia and publish articles in the JACRS.

Contributions by the ACRS Chapters and ACRS member organisations to the UNRSC are welcome. Please contact Chika (journaleditor@acrs.org.au) so that the ACRS can share with the UNRSC the significant road safety activities we are undertaking in our continued efforts to reduce road trauma as well as to conitrubte to the UNRSC activities.

Diary

20-23 February 2018
XV PIARC International Winter Road Congress
Gdansk, Poland
https://www.piarc.org/en/calendar/International-Winter-Road-Congresses-World-Road-Association/International-Winter-Road-Congress-Gdansk-2018/

7 March 2018
Road Safety Conference
Coventry, UK
https://www.rospa.com/events/road/

20 March 2018
11th ASECAP Road Safety Conference
Brussels, Belgium
http://www.asecap.com/eventasecap.html?layout=edit&id=167

20 – 23 March 2018
Intertraffic
Amsterdam, Netherlands
https://www.intertraffic.com/amsterdam/

26 – 28 March 2018
PPRS 2018
Nice, France
http://www.pprs2018.com/en/

16 – 19 April 2018
Transport Research Arena
Vienna, Austria
http://www.traconference.eu/

25 April 2018
Young Driver Focus 2018
London, UK
http://youngdriverfocus.org.uk/

29 April 2018
28th Australian Road Research Board (ARRB)
Brisbane, Australia
https://www.ivvy.com/event/ARRB18/

2 – 4 May 2018
SURF 2018
Brisbane, Australia
https://www.ivvy.com.au/event/SURF18

23 – 25 May 2018
ITF Summit 2018: Transport Safety and Security
Leipzig, Germany
http://2018.itf-oecd.org/

29 May – 1 June 2018
50th CIECA Congress 2018
Belfast, Northern Ireland
http://www.cieca.eu/calendar/799

10 – 13 June 2018
CARSP Conference 2018
Victoria, Canada
http://www.carsp.ca/carsp-conference/carsp-conference-2018/

12 – 15 June 2018
Velo-City
Rio de Janeiro, Brazil
https://www.velo-city2018.rio/

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/

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

Peer-reviewed Papers

Original Road Safety Research

Using Big Data for Improving Speed Enforcement and Road Safety Engineering Measures: An Application in Bogota, Colombia

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Key Findings

- Data show that speeding is a strong factor in the severity of traffic crashes and fatalities;
- 35% of Bogotá's reported traffic fatalities are located on 12% of the city's arterial roads;
- If speed enforcement is applied in the selected corridors, an estimated 78% of fatalities in these locations would be avoided;
- Agglomerating geocoded speed data and casualty data can help target speed enforcement to achieve the greatest safety impact with limited resources;
- The corridors selected for speed management registered 10.2% of vehicles' speeding.

Abstract

Enforcing speed limits is an effective measure to reduce traffic deaths and serious injuries as part of a comprehensive road safety strategy. In this paper, we explore the integration of geocoded traffic crash data and traffic speed sensors based on Wi-Fi/Bluetooth technology, to identify critical arterial road segments in Bogotá, Colombia. Big-data amalgamation and analysis allow a more effective focus in places with a high concentration of traffic crash victims and a high percentage of speeding traffic. This type of analysis helps inform the assignment of scarce traffic police resources to maximize impact. It also guides the effective location of speed cameras and traffic calming measures. Strict speed enforcement on the 17 arterial road segments identified in Bogotá may result in a 4% decline in the total number of fatalities per year citywide. As the current target for Bogota is a reduction of fatalities by 3.5% per year, these measures will meet and surpass this goal. Detailed speed data also show the hours and days of the week where speeding represents a higher risk, helping target enforcement. The proposed methodology can be replicated in other places and has the potential to be improved as additional data become available.

Keywords

Speed controls, big data, road safety, speed management, speed enforcement, traffic crashes, traffic crash victims

Introduction

Road crashes claim 1.25 million lives annually, with the highest road traffic fatality rates in low-income countries (World Health Organization, 2015). Speed is recognized as a major risk factor, especially for pedestrians (Organization for Economic Cooperation and Development, 2006; Rosén & Sander, 2009). Reducing average vehicle speed results in large reductions of traffic deaths (Greibe, 2005). Speeds are best reduced through a combination of infrastructure, legislation and enforcement measures (Organization for Economic Cooperation and Development, 2006). In low- and middle-income countries, traffic regulations are the most common measure for road traffic injury prevention, which has the best outcomes when combined with strong enforcement (Staton, C. et al., 2016).

Resources for enforcement are often limited, particularly in developing countries. Cities have a small traffic police force (Global Road Safety Partnership, 2008), and speed enforcement can be demanding (Sisiopiku & Patel, 1999). Camera enforcement may help increase effectiveness (Mountain, Hirst & Maher, 2005; Wilson, Willis, Hendrikz, Le Brocque, & Bellamy, 2010; Job & Sakashita, 2016), but implementation requires sizeable investment and faces strong opposition from car drivers. Infrastructure measures can be more effective than speed cameras in some cases (Mountain et al., 2005) but it may not be appropriate to use, for example, speed bumps in main roads.

In this context, deploying scarce police units for speed enforcement is important for local transport authorities to achieve maximum impact. Traditional approaches are based on geolocation of traffic fatalities and injuries and using heat maps to identify the segments of the road network with the greatest concentration of casualties (Bell & Schuurman, 2010). Nevertheless, heat maps may not correctly show the most hazardous segments for speed, as they depend on police records that often attribute "human error" as the probable crash cause or do not include a probable cause at all. It is also difficult to determine which of the vehicles involved in a collision were speeding (Doecke & Kloeden, 2011).

The rapid growth of information technologies provides new opportunities for complementing geocoded crash data. Big data has begun to be used to inform sustainable mobility planning (Semanjski, Bellens, Sidharta Gautama & Witlox, 2016), real time traffic operations and safety monitoring (Shi & Abdel-Aty, 2015). Application of such data is currently concentrated in industrialized countries, but there is a wide potential to leapfrog in developing countries.

This paper presents a case study of the applied combination of big data and geocoded traffic crash data to document opportunities and results in a developing city context. The first section presents basic information on road safety in Bogotá, and describes the data used in this study. The second section describes the methodology followed. The third section presents the results and analysis. The final section presents the conclusions, recommendations and suggestions for further research.

The aim of this study is to identify priority corridors for speed management in Bogotá based on speed and road safety data. It also aims to prove the methodology and the importance of combining and using big data to improve the impact of road safety measures.

Road safety in Bogotá and data used

In 2016, Bogotá had 7,980,001 inhabitants, 459,761 motorcycles and 1,120,279 automobiles (Bogotá Cómo Vamos, 2017). While motorization is relative low (198 motor vehicles per 1,000 people), and most trips are by public transport (44%) and walking (31%), congestion is a big problem. Average travel speeds in 2016 were 22 km/h for cars and taxis, 17 km/h for conventional buses, and 26 km/h for rapid transit buses (Bogotá Cómo Vamos, 2017). The number of traffic fatalities has oscillated between 500 and 600 over the last decade with no clear trend, while the average travel speeds have been declining (Camara de Comercio & Universidad de los Andes, 2017). 582 deaths and 15,008 road traffic injuries were registered in the city in 2016 (Bogotá Cómo Vamos, 2017). Most registered deaths in 2016 were pedestrians (48%), followed by motorcycle users (35%) and bicycle users (12%).

Bogotá has made excellent progress with geocoded traffic crash data. For this study, we used data from 2011-2015 provided by the local traffic authority (Secretaria Distrital de Movilidad). The database includes the geolocation for 38,350 casualties (1,645 fatalities and 36,705 injuries).

In 2016, the city launched a traffic control centre with state-of-the-art traffic sensors, including 350 Wi-Fi/Bluetooth devices capable of detecting individual speeds for road segments and full corridors, 160 automatic traffic counting devices, 12 automatic bicycle counting devices, and CCTV Cameras to monitor 100 intersections (Secretaria Distrital de Movilidad, 2015). This case study used the data of the first week of September 2016, which is considered representative as a typical week, as there are no vacation periods or holidays during this time of year.

Speed data for Bogotá is collected by a Wi-Fi/Bluetooth device that captures mobile phone signals as they cross intersections. Most signals come from smart phones with open Wi-Fi or Bluetooth technology. When the same mobile phone is captured by another device in another intersection, the time passed between a first and a second intersection is recorded. The time recorded is assigned to the segment between the two devices that captured the cell phone. Segment lengths can vary from 100 meters to 4,000 meters. Since the distance between the devices is constant, with this information it is possible to automatically calculate the speed of the cell phone movement in the segment. Although the speed data is generated by the mobile phones, not vehicles, the speed captured corresponds to the average speed of each vehicle in each segment. The system also registers the time and date of the captured phone and the identification number of the segment where it was captured. Data is anonymized and impossible to track back.

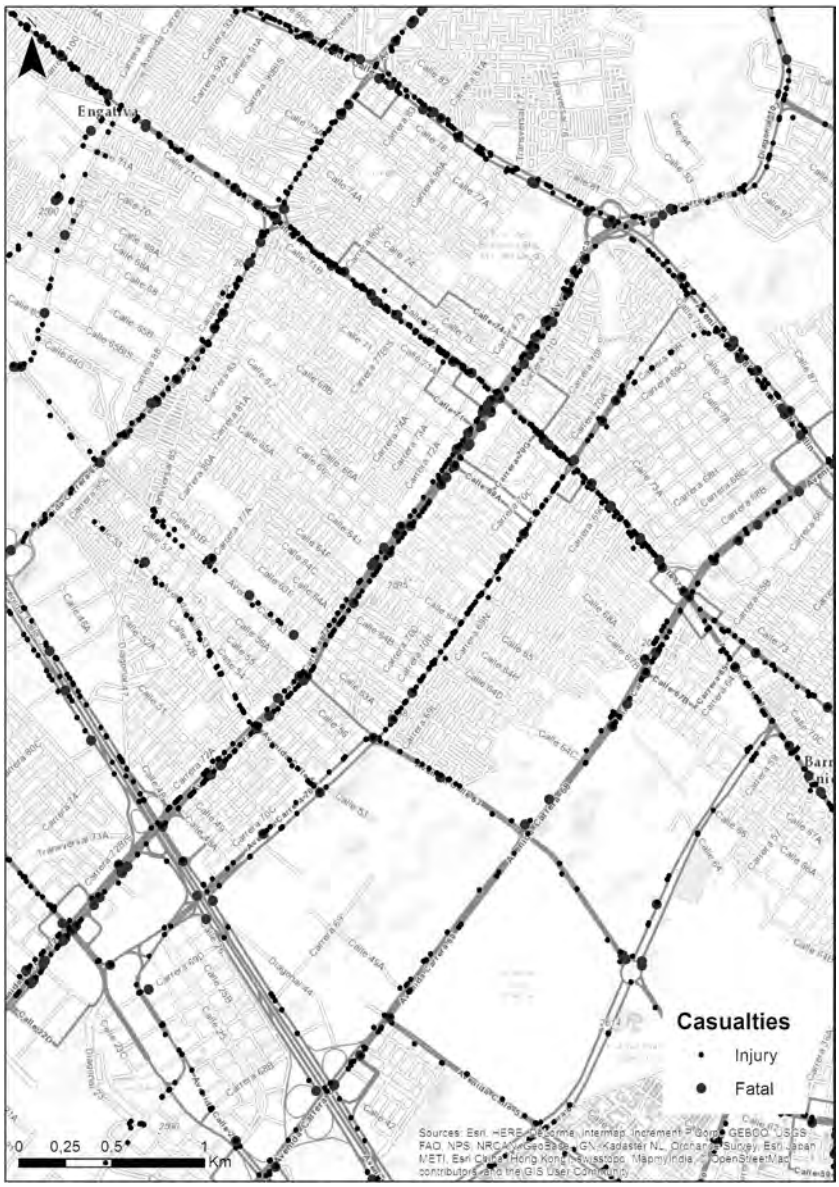

Figure 1. Example of Geolocation of Casualties after Data Processing. Source: Prepared by the Authors based on data provided by Secretaria Distrital de Movilidad, 2017

The speed database for Bogotá has close to 1.46 million records, and collects around 300 samples of speed per hour per road segment every week, although not all vehicles are tracked. The minimum speed registered is 4 km/h in order to exclude walking trips, and speed is not differentiated by type of vehicle; hence the sample contains speed measures for: bicyclists, motorcycle users, car and truck drivers and passengers, and public transport passengers. The lack of differentiation between vehicle types could potentially cause a bias, because most of the recorded speeds in an arterial road could be from public transport users, especially when BRT corridors are present. Nevertheless, this data is likely more reliable than the methodology used in the past to sample travel speeds, which was based on a vehicle traveling three to four times along city corridors. In contrast, the sample collected by the Wi-Fi/Bluetooth devices generates more than one million trip records per week.

The speed limit considered for the analysis is 60 km/h in all segments. This is because the highest posted speed limit in the city is 60 km/hour, and as a result drivers believe that the speed limit in all arterial roads is 60 km/h. In fact, the current law states that the speed limit in Bogota is 80 km/h unless posted differently (Congreso de la República de Colombia, 2002). Nevertheless, traffic police carry out speed control based on a 60 km/hour limit.

Methods

The first step of the process was to categorize arterial road segments according to the number of fatalities per year. This required data processing to geolocate specific road segments. Only the data close to (less than 50 meters away), or on, arterial roads was considered for the analysis (Figure 1). During the processing some errors in geocoding,

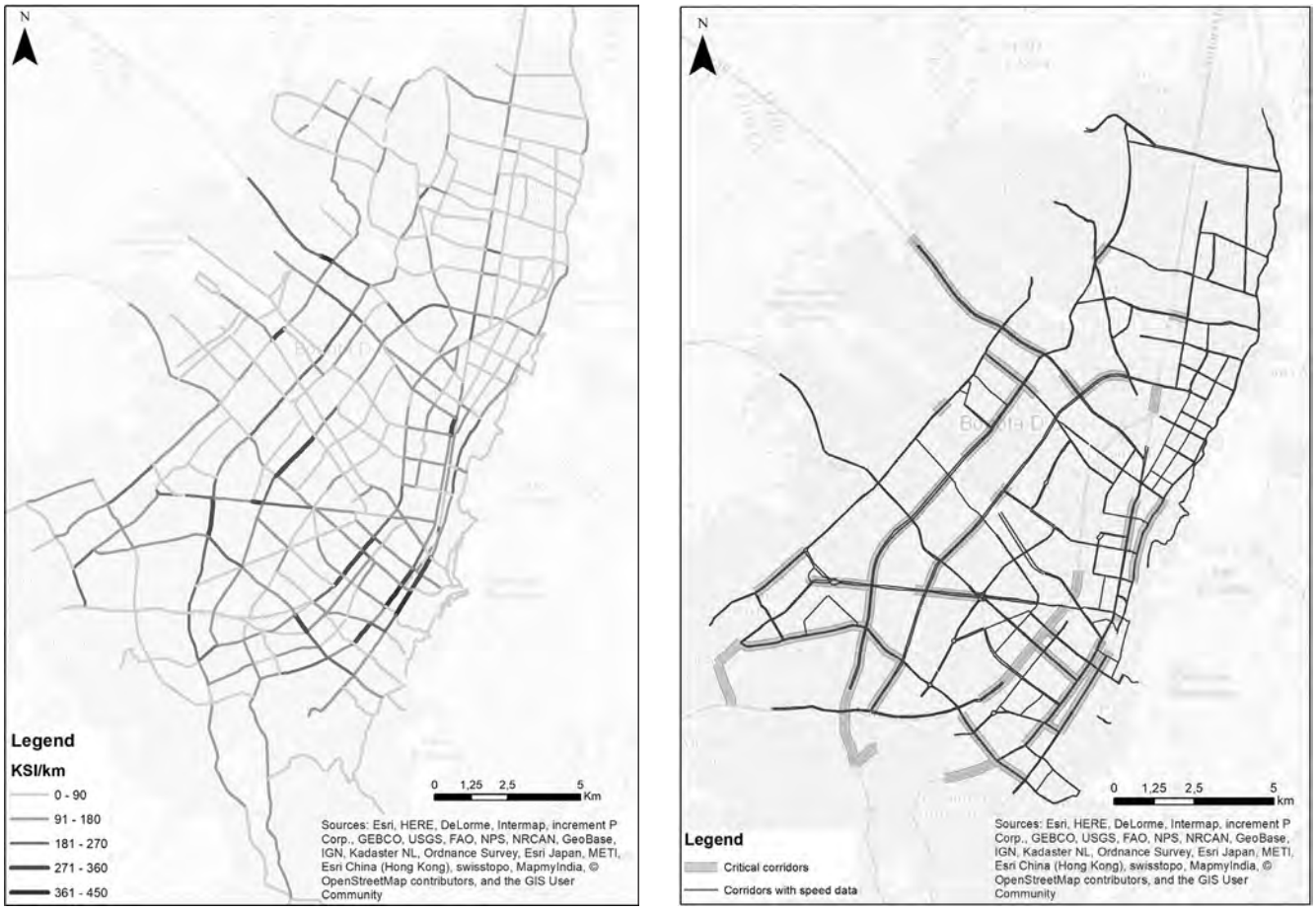

Figure 2. Casualties (KSI) per Km and Selected Critical Links (>35 casualties/km/year). Source: Prepared by the Authors based on data provided by Secretaria Distrital de Movilidad, 2017

were identified, both in the police report format and in manual data entry. As a result, the data to has an estimated error distance of 50 meters. However, the data was still sufficient to categorize road segments thanks to the high number of victim records available (38,350) and relative good precision. The number of casualties per kilometre was calculated, and arterial segments with more than 35 casualties per kilometre per year and with high speeds identified were selected as critical (Figure 2). As the Wi-Fi/ Bluetooth detectors are attached to traffic lights, highways without signalized intersections were not included in the analysis.

Speed distribution was then analysed for the critical segments. The proportion of vehicles travelling at more than 60 km/h in each of the critical corridors was calculated. This speed was used as a point of reference since it is the highest speed limit posted on arterial roads. Seventeen segments were identified as having more than 35 casualties per year and more than 5% of the traffic exceeding 60 km/h. These were recommended for targeted speed enforcement (Figure 3).

Finally, the fatality reduction potential was estimated using a formula developed through meta-analysis of speed control strategies in Norway (Greibe, 2005):

$$F_1 = F_0 \left(\frac{V_1}{V_0}\right)^{3.6} \quad (1)$$

where:

- F_1 is the number of fatalities after the speed control measure
- F_0 is the number of fatalities before the speed control measure (32 fatalities per year in all segments)
- V_0 is the average speed before the speed control measure (55 km/h)
- V_1 is the average speed after the speed control measure (35 km/h). The after speed was estimated assuming all vehicles comply with the speed limit of 60 km/h. The distribution after was estimated as if vehicles speeding were proportionally distributed between 0 and 60 km/h after speed management implementation, according to the proportion of vehicles travelling in that range before
- 3.6 is a coefficient estimated from multiple before and after studies for fatalities. The coefficient for estimating the change in injuries is 2.

According to this formula, if speed control is applied in the 17 segments, assuming a 100% compliance with the speed

Figure 3. Segments combining more than 35 casualties/year and 5% of the traffic exceeding 60 km/hour. Source: Prepared by the Authors based on data provided by Secretaria Distrital de Movilidad, 2017

limit, an estimated 78% of fatalities in these locations would be avoided (the number of fatalities would decrease from 32 per year to 7) and the amount of serious injuries would decrease by 60% (the number of traffic related injuries would decrease from 732 per year to 292). Such a reduction in fatalities would generate a reduction of the total annual fatalities in the city by 4% (25 fatalities). As the city has established a formal goal to reduce fatalities by 3.5% per year as in the District Road Safety Plan 2017-2026 (Alcaldía Mayor de Bogotá, 2016), applying strict speed controls on the selected segments would be sufficient to achieve the overall city goal. This finding shows the potential benefit of combining the two data sources (geocoded crash data and vehicle speeds) for the selection of segments for speed enforcement.

Analysis

The data analysis presented in this paper identified the corridors with the highest potential to reduce the number of traffic collisions. The analysis identified corridors which had both a high number of annual casualties (over 35) and a high proportion of vehicles speeding (over 5%) to be targeted for speed enforcement, (Figure 4).

On average, 35% of Bogotá's reported traffic fatalities are located on corridors identified as critical, although they only represent 12% of the length of the city's arterial network (and 0.7% of the length of the total road network). Only 4.8% of the vehicles analysed in all critical corridors exceeded the maximum posted speed limit of 60 km/h (5,622 out of 118,332 registered). The corridors selected for speed enforcement registered an average of 10.2% of vehicles speeding over 60 km/h (4,110 out of 40,348 registered) and represent 2.9% of the length of arterial roads.

In addition to the identification of critical segments for speed enforcement, the detailed data generated by the Wi-Fi/Bluetooth devices is also useful to identify the time and day of the week in which enforcement is most needed. Figure 5 shows the percentage of vehicles speeding in the critical corridors by time of day and the number of vehicle samples per hour (each segment is sampled around 300 times per hour). As shown, speeding over 60 km/h is higher between midnight and 5:00 am. At 3:00 am, almost 20% of the vehicles are exceeding 60 km/h. There a lower proportion of traffic speeding on Saturdays and Thursdays than other days (0:00 to 5:00), probably due to specific events during the week analysed (for example precipitation). Mondays have a higher proportion of vehicles speeding than other weekdays, with more than one quarter of the traffic exceeding 60 km/h at 2:00 and 3:00 am (Figure 6).

The data also suggests that speeding is a risk factor in road traffic fatalities. As indicated in Figure 7, there is a higher percentage of fatalities between 0.00 and 5:00 am which coincides with the hours with higher rates of speeding.

Conclusions, recommendations and further research

The case study shows the potential of combining traditional geocoded traffic crash data with detailed speed data obtained from advanced sensor technology. The additional data analysis can inform focused efforts not just in locations where there have been serious traffic collisions, but in places where speeding represents a potential risk. This helps assigning scarce traffic police resources to maximize impact. Strict speed enforcement on the segments selected through the data analysis may result in a 4% decrease in total fatalities annually, which is significant as it corresponds with the annual road safety target for the city. Detailed speed data also display the time, days of the week and segments where speeding is a risk, helping to plan for more efficient enforcement.

The process described here can be further improved. Speed sensors in Bogotá currently detect Wi-Fi/Bluetooth signals to derive traffic speeds without differentiating between the type of vehicle or number of occupants. With some calibration, it may be possible to differentiate between road users. In addition, the detailed speed data was not available in critical segments of urban expressways for the time period analysed. This constraint has now been addressed, as additional detectors have been deployed. Data from fixed detectors could be also combined with GPS data from

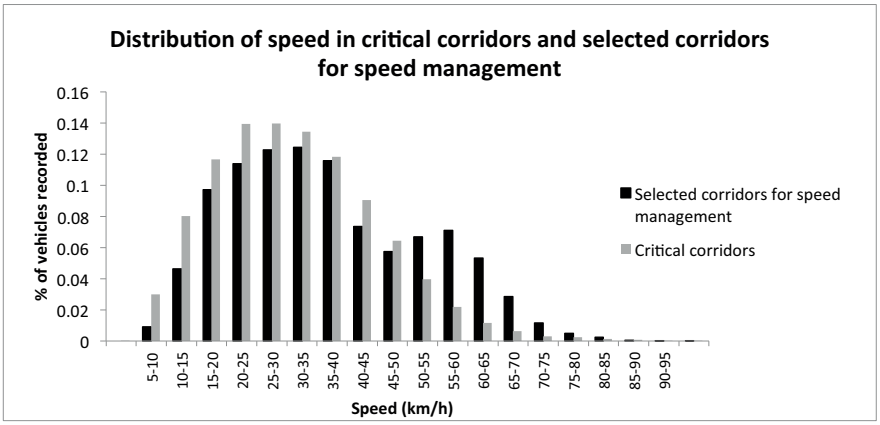

Figure 4. Distribution of vehicle speeds in critical corridors (only corridors in arterial roads with 35 casualties/km/year with speed data) and corridors selected for speed management (critical corridors with more than 5% of vehicles exceeding 60 km/h). Source: Prepared by the Authors based on data provided by Secretaria Distrital de Movilidad, 2017

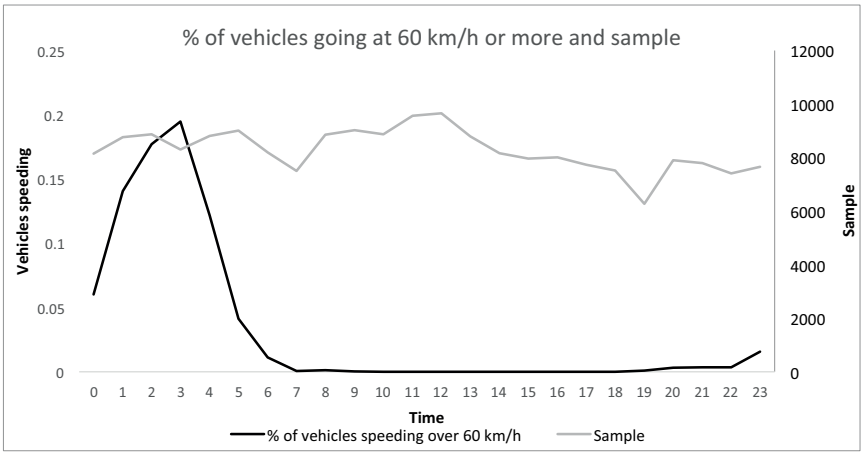

Figure 5. Percentage of Vehicles Speeding over 60 km/h by time of the day (2016) and sample size. Source: Elaborated by the Authors based on data provided by Secretaria Distrital de Movilidad, 2017

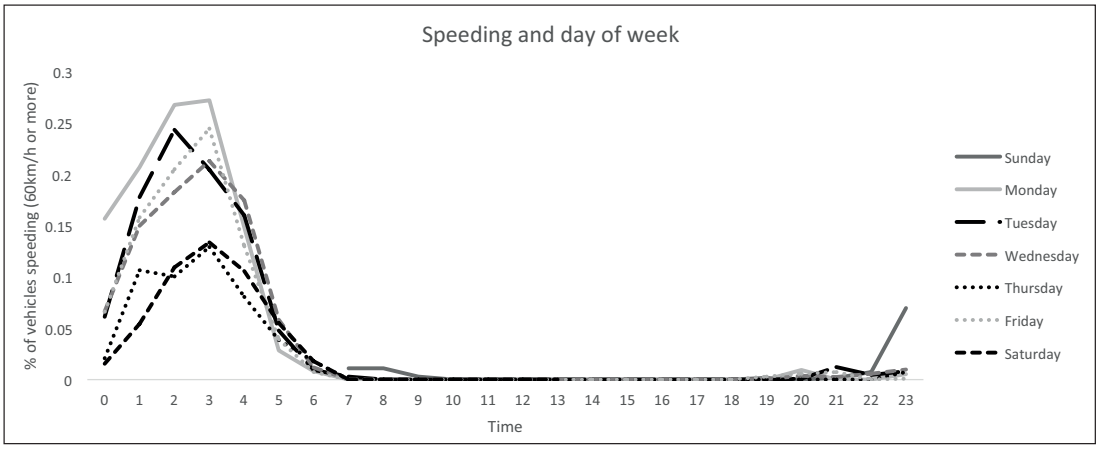

Figure 6. Percentage of Vehicles Speeding over 60 km/h by time and day of the week (2016). Source: Elaborated by the Authors based on data provided by Secretaria Distrital de Movilidad, 2017

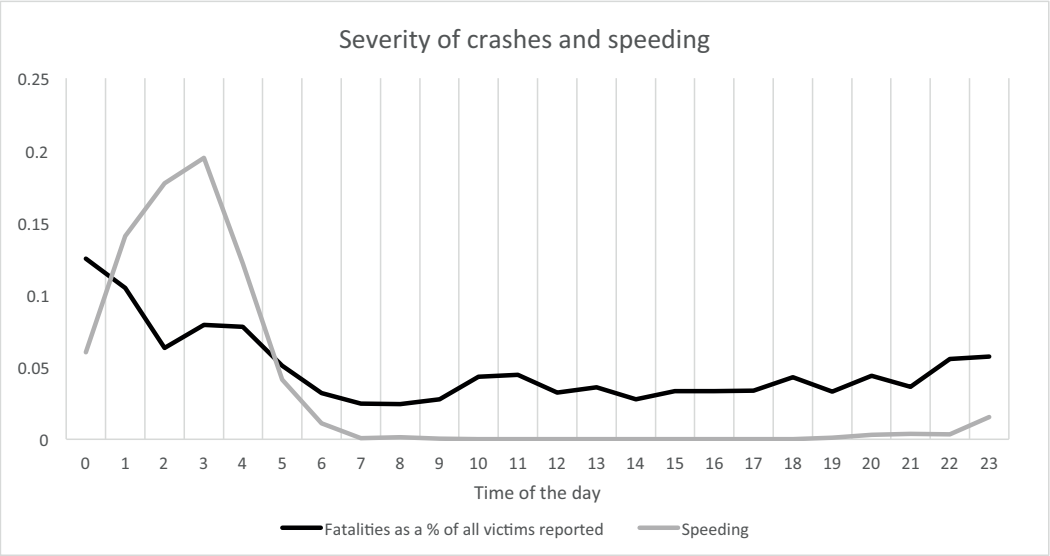

Figure 7. Comparison of percentage of Fatalities (2016) and percentage of Speeding by time of the day. Source: Prepared by the Authors based on data provided by Secretaria Distrital de Movilidad, 2017

vehicles on the road, for instance taxicabs (World Resources Institute, 2017).

The cost of the new traffic control system in Bogotá was USD 10.1 million (Secretaría Distrital de Movilidad, 2015). It includes many other components in addition to the Wi-Fi/Bluetooth speed detectors. The use of GPS data from vehicle fleets may be more cost effective than Wi-Fi/Bluetooth detectors for cities that have yet not made the investment in dedicated speed detecting devices.

This analysis was conducted using historical traffic crash data (2011-2015), and speed data from a one-week period during September 2016. There is the potential to generate continuous real-time data in the future, which may help in multiple additional analyses.

In this case, the focus was targeting police enforcement, but the analysis presented here could also be used to deploy speed cameras and to introduce physical traffic calming measures, such as rumble strips or narrower lanes, which have proven effective in reducing speeds (Mountain et al., 2005).

In addition to informing strategic speed enforcement, the speed data generated will be very helpful to develop a proactive rather than a reactive approach to road safety, and to conduct a before and after analysis of interventions.

In this case study, speeding was set above 60 km/h, which is the highest posted speed limit in urban arterials in Bogotá. There are segments with lower speed limits, but data on posted speeds was not available at the level of detailed required. Integrating data on posted speeds would make the speeding analysis even more accurate. Data may be also helpful in establishing safe speed limits.

There is a wide potential to integrate big data sources to make informed decisions in urban mobility, establish speed limits and target police enforcement. This pilot application in a developing city illustrates a replicable methodology and it also shows opportunities to further improve the impact of road safety interventions.

Acknowledgements

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Mitigating localised sand accumulation using wire rope safety barrier

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Key Findings

- Traditional measures to mitigate sand accumulation on the road incur high costs;
- Road safety barriers can contribute to sand accumulation within the carriageway;
- The porosity of barriers can affect the distribution of windblown sand;
- Wire rope barriers offer a potential alternative to mitigate sand accumulation.

Abstract

Sand accumulation on highways is an ongoing problem for road authorities in arid areas across the globe. Typical methods to prevent sand accumulation on highways include landscaping, sand fences and desert resistant vegetation; but these incur high construction and maintenance costs. This paper discusses the impact of different road safety barrier types used in areas prone to sand accumulation and provides a case study of the impact of replacing an existing steel W-beam median barrier with a trial section of wire rope barrier. The trial proved to be successful in mitigating localised sand accumulation and is recommended for consideration in desert environments.

Keywords

Sand Accumulation, Wire Rope Barrier, Median, Highway

Introduction

Road authorities across the globe with desert environments have an ongoing problem of preventing sand being deposited on the highway. As sand is blown across the road, structures such as road safety barriers can be a major cause of localised sand accumulation. Accumulated sand can have a detrimental impact on vehicle handling and adversely affect the safety performance of the barrier.

A Middle East State experiencing frequent sand accumulation on the road has looked at various ways to resolve this problem. Current methods include sand fences, extensive roadside vegetation, and sand clearing operations. This paper proposes an alternative solution that forgoes the need for carriageway sand clearing and closing off lanes to traffic during strong wind periods.

Literature Review

Traditional approaches to mitigate sand accumulation on transport infrastructure such as roads, railways and canals are based on prevention or shielding measures.

Heshmati & Squires (2003) documented two complementary types of measures to address shifting sands. One is to protect existing vegetation on the sand dune or plant trees, shrubs and grasses if there is none or little (these are called biological measures). The other method is to set up physical barriers on sand dunes, such as wire mesh fences, or to cover the surface of the sand dune with straw, clay, tree branches, bamboo, reeds stalks, cobblestone and petroleum chemicals etc. (these are called mechanical measures). Heshmati & Squires suggest that mechanical measures are only effective on their own in the short to medium term and that biological measures will need to be used to complement the mechanical measures for long term effectiveness.

Zhibao et al. (2004) considered methods employed in China to protect highways from sand blowing from the Taklimakan Desert. They suggest that effective measures to control windblown sand include upright clustered reed fences, reed checkerboard barriers, upright reed fences, upright nylon net fences, chemical and clay fixers and artificial vegetation, or a combination of these measures.

Zhang et al. (2010) highlighted that wind-blown sand along the Qinghai-Tibet Railway (opened in 2006) presents a particular challenge due to the low air pressure and air density on the Tibet Plateau. Methods employed to control windblown sand included rocky checkerboard sand barriers, sand-blocking fences, sand-deviating boards and wind-weakening leaf barriers.

Sand Accumulation on an Expressway class road

The road studied is a major expressway in Qatar comprising two 4-lane carriageways, a 3m hard roadside shoulder, 2m hard median strip and a 120 km/h speed limit. Both carriageways are separated by a 16m wide median with two rows of steel W-beam barriers (two-row). Street lighting is provided within the median.

The studied area has an arid desert-like climate and rural feel, characterized by hot summers, scarce rains and warm winters. There are migrating sand dunes close to the expressway and the area typically experiences hot, dry and often windy weather.

Despite the use of sand fences on the north side of the carriageway, sand is able to flow past these fences and onto the road. The sand barriers are approximately 70 to 80m long and positioned diagonally with the road, with the nearest edges being set back approximately 50m from the edge of the road and the furthest edge being 100m away. The barriers are 1.5 to 2.5m high and have a porosity of approximately 0 to 20 percent. Sand regularly builds up immediately beyond the fences during peak sand drift seasons. The two rows of steel W-beam safety barrier on the median further disrupt the flow of sand particles that flow onto the road, which leads to a buildup of sand on the median and within the carriageway. Figure 1 shows an example of heavy sand accumulation after a period of strong wind.

This presents a significant on-going maintenance liability for the road authority to remove sand accumulated within the third and fourth lanes (fast lanes) of the eastbound carriageway during and after periods of strong wind.

KBR (2014) considered options to manage sand accumulation based on a combination of roadside biological and mechanical measures (Figure 2). However, such a suite of mitigation measures was anticipated to incur substantial establishment costs as well as being difficult to maintain in a remote environment.

Figure 3 shows a section of expressway in an urban fringe environment between Doha City and the Hamad International Airport (refer to Figure 6 regarding location). The roadside landscaping implemented in this case is similar to that recommended in Figure 2.

The highway infrastructure and landscaping shown in this photo was implemented as part of a multi-billion dollar roading project to connect Doha with the new airport. Because this site is located on the fringes of urban development, and possibly due to the extensive use of roadside vegetation, it is not typically subject to wind blown sand problems.

However, this level of roadside treatment is not considered feasible for the majority of the remote rural highway network, nor practical in terms of water source and maintenance issues. With the studied road being located in a remote dry desert climate, biological measures requiring substantial water resources were considered difficult to establish and, ultimately, not sustainable. Furthermore, existing methods to prevent sand accumulation along various sections of road (i.e. using sand barrier fences combined with routine maintenance to clear sand around the fences) has not completely prevented the sand from reaching the carriageway.

KBR (2014) also considered the effect of solid versus porous fences on sand accumulation. The report suggested that a porous barrier could potentially improve the distribution of windblown sand across the carriageway (Figure 4). It was therefore hypothesized that a more porous road safety barrier in the median also had the potential to improve the distribution of windblown sand. This led to a trial involving

Figure 1. Heavy sand build up after a period of strong wind

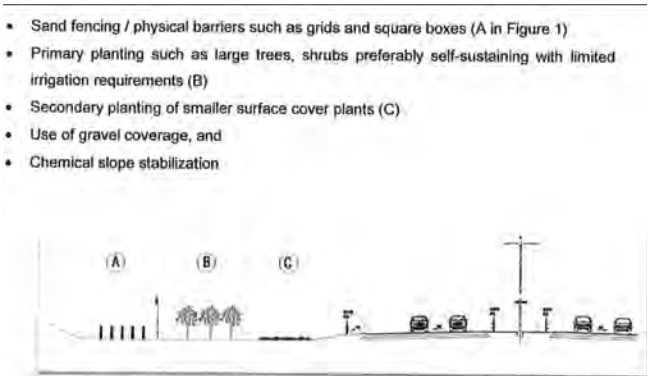


Figure 2. Illustration of roadside mitigation for sand accumulation (KBR, 2014)

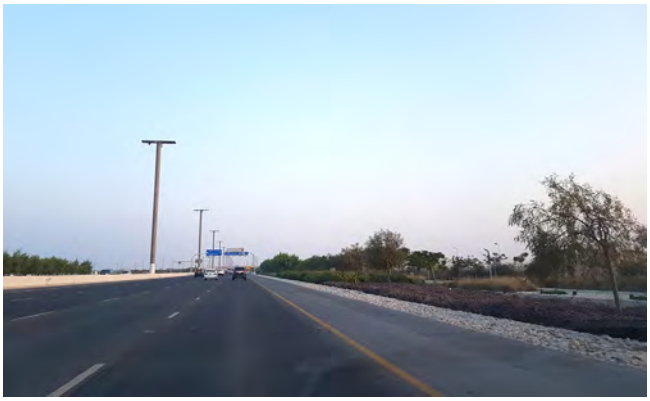


Figure 3. Example of extensive roadside landscaping and vegetation

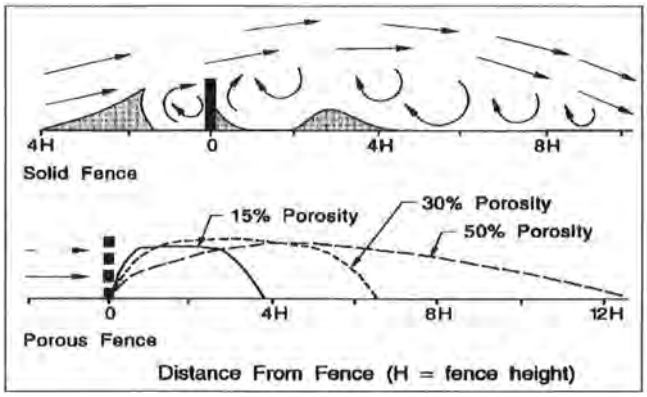


Figure 4. Illustration of sand flows affected by solid and porous fencing or barriers (KBR, 2014)

the replacement of a section of the two-row steel W-beam barriers with wire rope barriers.

Unfounded concerns over wire rope barrier performance in the past have sometimes hindered their liberal adoption by road authorities. There are, however, numerous studies to support the effectiveness of wire rope safety barriers. Three studies worth mentioning include Ohio's Department of Transport (2005), WSDOT (2013) and Cooner. S. et al (2009). These reports support the substantial body of evidence and research which suggests that wire rope safety barriers reduce the rate and severity of vehicle collisions and are more forgiving than other barrier types.

Whilst there is a common perception that wire rope safety barriers are especially hazardous for motorcyclists, this is not supported by research. Melendy, L. et al. (2006) found that most riders are separated from their motorcycles and are sliding on the ground when they contact a barrier. The safety risk motorcyclists experience in this situation, i.e. the posts, is similar for both wire rope barriers and steel W-beam barriers. Daniello, A. et al. (2011) found no appreciable difference in fatal and severe injuries when comparing wire rope safety barriers and steel W-beam barriers. While concrete barriers performed better for a sliding motorcyclist, because there are no posts, none of the barriers protect an upright motorcyclist from being thrown over the top and into a roadside hazard or opposing traffic. It should be noted that concrete barriers would not be a suitable solution in this particular case because they are particularly prone to sand accumulation. Figure 5 illustrates the extent of sand accumulation caused by a concrete barrier installed at a weigh station located on the same road as the trial site.

In summary, it can be stated that wire rope safety barriers represent an effective road safety solution and are the most forgiving type of barrier with the lowest overall ratio of deaths and serious injuries from barrier collisions. It was also hypothesised that a more porous wire rope barrier system had the potential to mitigate the accumulation of windblown sand by allowing sand to pass freely through the barrier.

Installation and Observations

A trial was undertaken on a remote section of Salwa Road, approximately 80 kilometres west of Doha, Qatar, to replace sections of existing steel W-beam median barriers (Type N2 under the European EN1317 specification) with a wire rope safety barrier system. The wire rope safety barrier comprised a four-strand high tension system to Test Level 4 under the US NCHRP-350 specification (Make: Armorwire DSR galvanized, grade 1320 RHL). Figure 6 shows the general location of the trial site, noting the remoteness from any developed areas. Figure 7 provides the general climatic conditions of the studied area and Figure 8 shows the installed wire rope barriers on the median.

The wire rope safety barriers were installed between March and August 2015, with the westbound wire rope safety barrier being completed on 31 May 2015. There was a period of evaluation with one row of wire rope barrier and one row of steel W-beam barrier (refer to Configuration 2 in Figure 9) before the eastbound wire rope safety barrier was finally completed on 10 August 2015.

Eight site visits were carried out between June 2015 and March 2016 during and following strong wind periods to identify the extent of sand accumulation on the carriageway for each of the three barrier configurations: 1) two-row W-beam, 2) split wire rope / W-beam, and 3) two-row wire rope.

The site visits were undertaken at least 6 hours after forecast wind speeds above 20 km/h were experienced (assessed using local weather forecasting information on projected wind speeds) and at various time periods after the start of the strong wind periods so that sand piles were able to form over different durations.

Figure 9 provides the general layout and the sequence of barrier types installed:

Prior to the trial, with the existing two-row W-beam median barriers (Configuration 1), sand would accumulate in significant deposits on the hard median strip and within the third and fourth (fast) lanes. Figure 10 provides a typical

Figure 5. Example of sand accumulation associated with a concrete barrier

example of sand accumulation with the two-row W-beam barriers. During, and following, strong wind periods the third and fourth (fast) lanes of the eastbound carriageway would be closed to live traffic using traffic management measures.

When the first wire rope barrier was installed on the westbound carriageway (Configuration 2: split wire rope / W-beam barriers), there was a noticeable effect of sand being deposited further across the eastbound carriageway in the second lane. Figure 11 shows the shift in sand accumulation patterns under Configuration 2 with the split wire rope / W-beam barriers.

This situation required even further lane closures with sand accumulating across into the second lane. This result also highlights the need to carefully consider the potential impact of road safety barrier location and the sequencing of barrier types on potentially adverse sand accumulation patterns.

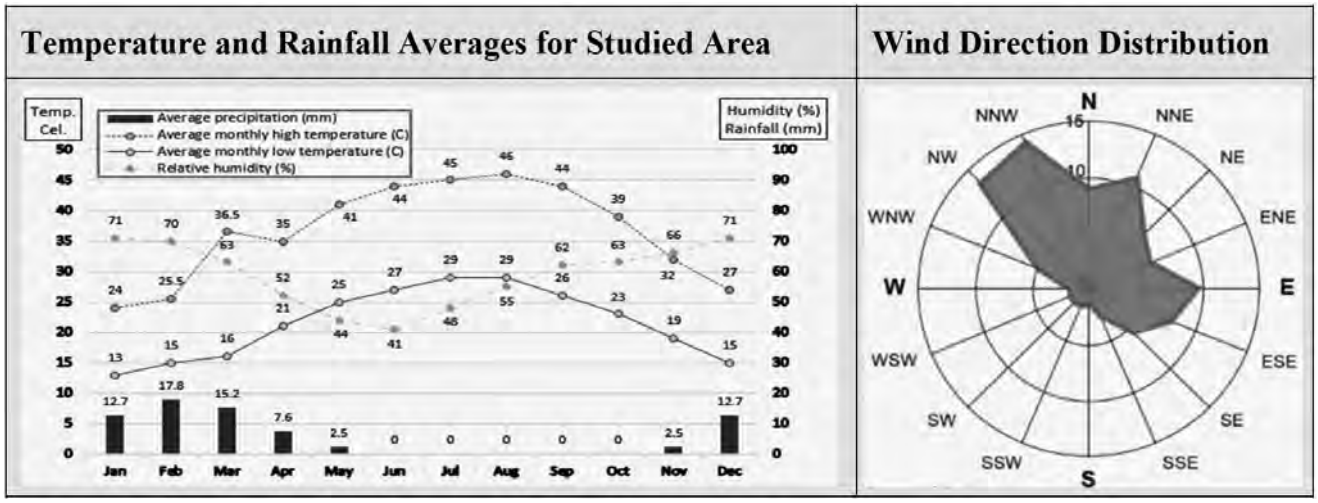
Once the second row of wire rope safety barrier was installed on the eastbound carriageway (Configuration 3: two-row wire rope), it was clear to see that sand flows were

Figure 6. Location map of observed road (Salwa Road, Qatar)

less obstructed by the barriers. Figure 12 shows a typical observation where sand is relatively free to flow across the road without resulting in significant deposits.

A summary of the site observations for the three different median barrier configurations is presented in Table 1.

Sand accumulation records in Table 1 indicate where stationary sand piles had developed to the point where they were considered a potential hazard to vehicle handling and / or warranted lane closure. The table summarises the sand accumulation patterns that were observed for



Information Sources: www.windfinder.com, www.weather.com, information obtained in August 2017. Note: Wind Direction Distribution speed in knot

Figure 7. General climatic conditions of study area

Figure 8. Wire rope barrier installation (August 2015)

Figure 10. Sand accumulation with existing two-row steel W-beam barriers

the three different median barrier configurations. These shifts in sand accumulation patterns were clearly observed from the formal site investigations as well as being further supported anecdotally through ongoing correspondence with Contractors before, during and after installation works.

There were no significant sand deposits observed under the two-row wire rope safety barrier configuration as a result of wind speeds of 20 km/h or greater. Moreover, the wire rope safety barrier's vertical surface area is estimated to have a high porosity value of over 90%, compared to approximately 60% for a W-beam barrier (estimated from NZTA, 2017), which allows the windblown sand to pass through and clear the wide carriageway on the downwind side of the median. This is compatible with the anticipated sand flow and deposits diagram shown above in Figure 4 and supports the hypothesis that a more porous wire rope barrier system improves the distribution of windblown sand. The results also suggest that wire rope safety barriers in both directions are needed within the median for the sand to flow past the carriageway completely.

Whilst not the main objective of the study, observations during construction identified adverse sand accumulation patterns with the split wire rope / W-beam barrier configuration. The two split barrier configurations noted in

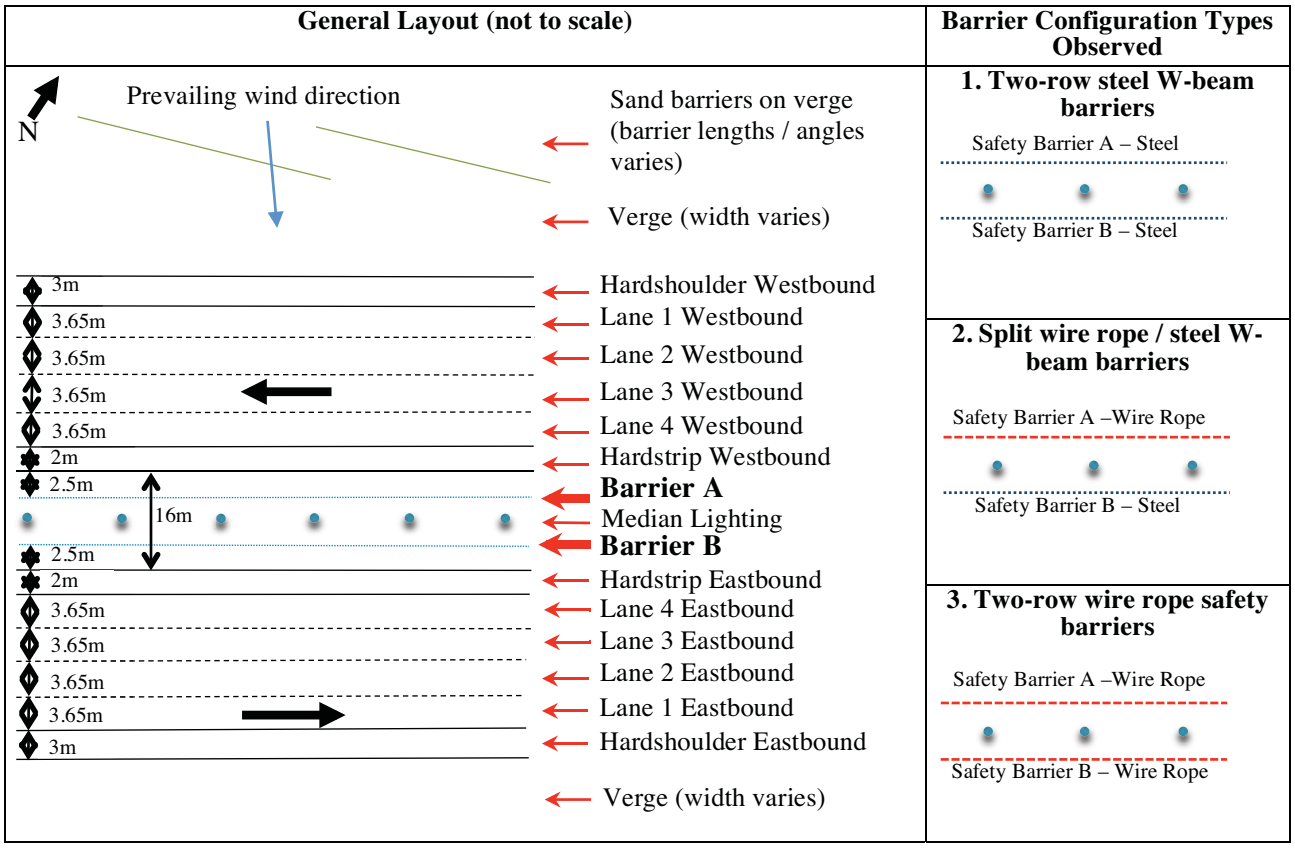


Figure 9. Indicative layouts of median barrier configurations observed

Figure 11. Sand accumulation with a split wire rope and steel W-beam barrier configuration

Figure 12. No sand accumulation with two-row wire rope barriers

Table 1. Sand accumulation observation results

Date/Time of Visit	Wind Direction	Wind Speed (km/h)	Temp. (degrees Celsius)	Barrier Configuration	Sand Accumulation Position on Eastbound Carriageway				
					Hard strip	4th Lane	3rd Lane	2nd Lane	1st lane
09.06.15 12PM	South	27	41	Two-row W-Beam	■	■			
09.06.15 12PM	South	27	41	Split W-Beam / Wire Rope			■	■	
22.06.15 9AM	South-South-East	45	42	Two-row W-Beam	■	■			
22.06.15 9AM	South-South-East	45	42	Split W-Beam / Wire Rope	■	■	■	■	
09.07.15 10AM	South-South-East	27	38	Two-row W-Beam	■	■	■		
11.10.15 12PM	South-East-South	35	37	Two-row W-Beam	■	■			
11.10.15 12PM	South-East-South	35	37	Two-row Wire Rope					
07.12.15 9AM	South-East	47	17	Two-row W-Beam	■	■	■		
07.12.15 9AM	South-East	47	17	Two-row Wire Rope					
03.01.16 11AM	South-East-South	27	20	Two-row W-Beam	■	■	■		
03.01.16 11AM	South-East-South	27	20	Two-row Wire Rope					
14.02.16 2PM	South	20	21	Two-row W-Beam	■	■			
14.02.16 2PM	South	20	21	Two-row Wire Rope					
24.03.16 8AM	South-South-East	24	19	Two-row W-Beam	■	■	■		
24.03.16 8AM	South-South-East	24	19	Two-row Wire Rope					

Note: the wire rope installation on the eastbound carriageway (final installation) was over a longer length than the westbound carriageway (first installation), which is why it was possible to observe different combinations during the same site visit.

Table 1 were recorded immediately adjacent to the two-row W-beam sections during a pass through the site while construction was underway. The shifting of sand from lanes 3 and 4 into lane 2 with the split configuration underlines a further important consideration to note when locating and combining various barrier systems. It also highlights the potential for shifting of sand patterns during construction as part of any safety barrier retrofit works.

Two other substantial lengths of highway in Qatar that have been treated with wire rope median barriers include the Lusail-Salwa Temporary Truck Route and Ras Laffan Road (Figure 6), which have been operational since Winter 2014 and Autumn 2015 respectively. Both highways comprise two lanes in each direction with a wide central median.

Correspondence with the Public Works Authority Road Maintenance Department suggests, anecdotally, that there have been no instances of substantial sand accumulation on these routes that required closing of running lanes or clearance work.

Conclusions

Sand accumulation on highways is an ongoing problem for road authorities across the globe, particularly in environments with desert landscapes such as Africa, the Middle East and Asia. Sand accumulated on the highway can lead to serious loss-of-control and run-off-road crashes. Typical methods to prevent sand accumulation on highways include landscaping, sand fences and desert resistant vegetation. Such measures can potentially generate significant establishment and maintenance costs and challenges, particularly in remote locations. Even with these measures in place, sand may continue to blow onto and across the road.

As sand is blown across the road, roadside structures such as road safety barriers can be a major cause of localised sand accumulation. This not only has the potential to adversely affect vehicle handling but could also reduce the safety performance of the barrier.

A two-row wire rope median safety barrier arrangement was trialed to replace the existing steel W-beam barriers on an expressway class road passing through a dry desert environment and the effects were monitored during strong wind periods. The results indicated that the wire rope safety barriers allowed sand to flow almost unimpeded across the highway with no sand accumulation observed within the carriageway. Whereas, median barrier configurations that incorporated W-beam barriers resulted in the interruption of sand flow with significant deposits of sand accumulating within the carriageway.

There is a substantial body of evidence and research suggesting that wire rope safety barriers reduce the rate and severity of vehicle collisions and are more forgiving than other barrier types. This study suggests that wire rope safety barriers also offer significant potential as an alternative or supplementary measure to help mitigate localised sand accumulation. It is recommended that road authorities consider this wire rope treatment when conventional methods are not totally successful, or a comprehensive roadside landscaping treatment is not feasible.

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Crash Risk Models for a Motorcycle-Dominated Traffic Environment

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Key Findings

- Rear-end and sideswipe crash risk models for motorcycle-dominated traffic environments were developed;
- A new concept of Conflict Modification Factor (CoMF) was proposed for road safety assessment in circumstances where reliable crash data are difficult to obtain;
- The effects of risk factors on rear-end and sideswipe crashes for motorcyclists were assessed to improve the existing iRAP star rating system;
- The enhanced iRAP star rating system for motorcyclists in developing countries proposed in this study was found to produce reliable results.

Abstract

This paper presents a methodology to estimate the potentials of rear-end and sideswipe crashes for motorcycles moving in a motorcycle-dominated traffic environment on urban roads and examines their integration in the International Road Assessment Programme (iRAP) star rating system. The crash risk models developed are based on discrete choice models and traffic conflict techniques. The proposed methodology was validated using data collected on road segments from the city of Danang in Vietnam. The models' field validation shows that the developed methodology produces a good estimate of rear-end and sideswipe crash risk for motorcyclists and the enhanced iRAP star rating methodology produces most satisfactory results. It was found that risk factors such as front distance, longitudinal gap, lateral gap, lateral clearance, speed difference, and operating speed have a significant contribution to motorcycle crash risk and therefore they should be considered in the selection of remedial measures aimed at improving motorcyclist safety. While the paper is not intended to provide countermeasures, appropriate treatments may be developed using the proposed crash risk models and based on an assessment of the effect of risk factors on rear-end and sideswipe crashes.

Keywords

Motorcyclist Safety, Motorcycle-Dominated Traffic, Star Rating System, Rear-end Crash Risk, Sideswipe Crash Risk, Developing Countries

Glossary

D_{TSD}^{FM}	threshold-safety-distance for following manoeuvre scenario
D_{TSD}^{SM}	threshold-safety-distance for swerving manoeuvre scenario
e	base of the natural logarithm
$g(x)$	logit of the logistic regression model
La_{n-1}	lateral clearance beside the front vehicle
$Lo_{\mathrm{n}}^{\mathrm{n-1}}$	front distance
Lo_n^m	longitudinal gap between motorcycle and adjacent-following vehicle
$L(\beta)$	log-likelihood function
ln(y)	natural logarithm of variable y
Te_{n-1}	type of front vehicle
Te_m	type of adjacent-following vehicle
V_n^m	relative speed between motorcycle and adjacent-following vehicle
V_n^{n-1}	relative speed between motorcycle and front vehicle
v	speed of vehicle
α	swerving angle of motorcycles
β	coefficient of independent variables
$\pi(x)$	conditional probability that the outcome is presence
μ	mean of the lognormal distribution
σ	standard deviation of the lognormal distribution
τ	reaction time of motorcyclists
Φ	cumulative standard normal distribution

Introduction

Motorcyclists' safety is a major concern in a number of cities worldwide including most Southeast Asian cities where motorcycles are the predominant mode of transport. In recent years, although the number of passenger cars is increasing due to economic growth, motorcycling is still the predominant mode of urban transport in a number of low-and middle-income countries (LMICs) worldwide, particularly in most Southeast Asian cities due to affordability and flexibility in terms of movement and parking. Consequently, the number of crashes resulting in death and serious injury involving motorcycles in these countries is significant. According to the report of WHO (2015), the number of motorcycles accounts for 54.1% of the total registered vehicles in the Southeast Asian countries, and the proportion of crashes involving motorcycles accounts for 34% of the total road crashes in this region. However, in certain countries, motorcycles' crashes may reach about 70% of the total road crashes (Manan and Várhelyi, 2012). For example, in the city of Danang in Vietnam, motorcycles constitute over 80% of total traffic, and motorcycle crashes account for nearly 70% of the total road crashes (DoT, 2013). Similarly, in Indonesia, it has been reported that motorcycles account for 78.3% of the total vehicle population and 75% of fatalities in traffic crashes involved motorcyclists (Indriastuti and Sulistio, 2010). This issue has also been reported in Taiwan (Ming, Wucheng and Cheng, 2013) and Malaysia (MIROS, 2011).

In motorcycle-dominated traffic conditions, the manoeuvre behaviour of motorcycles were found to be major causes (or risk factors) contributing to motorcycle crash potentials (Indriastuti and Sulistio, 2010; Long, 2012; Ming, Wucheng and Cheng., 2013; Shiomi et al., 2013). In Vietnam for example, crash data revealed that "failed to keep safe following gap", "changing lanes improperly", and "failed to look properly" are three most common causes of motorcycle-involved crashes, accounting for 19.3%, 16% and 15.9% respectively (DoT, 2013). These risky movement behaviour of motorcyclists have resulted in a large proportion of rear-end and sideswipe crashes involving motorcycles. For example in Danang, the crash statistics show that rear-end and sideswipe crashes account for 25.9% and 36.3% of the total motorcycle crashes in urban environment respectively (DoT, 2013). Similarly, in Taiwan, it has been reported that rear-end and sideswipe crashes account for 20% and 32% of the total motorcycle-involved crashes on urban roads (Ming, Wucheng and Cheng, 2013). This issue has also been reported in Indonesia and Malaysia (Indriastuti and Sulistio, 2010; Manan and Várhelyi, 2012).

Although the movement characteristics of motorcycles have been found to be a significant factor contributing to motorcycle crashes, it seems that to date there are no models that take into account explicitly these risk factors. To this end, and to examine the effect of such manoeuvre behaviours of motorcyclists on crash risk, this study developed a methodology and associated models to estimate the potential of rear-end and sideswipe crashes associated with these manoeuvre characteristics for motorcycles moving in a motorcycle-dominated traffic environment of urban roads. The paper is not intended to provide treatment measures but engineers or decision makers may use the developed crash risk models to identify hazardous sites and develop appropriate countermeasures to improve motorcyclist safety.

Literature Review

Several researchers have examined the risk factors affecting the motorcycles' crash frequency in the traffic environment of low-income and middle-income countries by developing crash prediction models based on historical data and statistical methods. For example, Harnen et al. (2006) developed a model to estimate the frequency of motorcycle crashes at junctions of urban roads in Malaysia. They suggested that the flow of non-motorcycle on a major road, the approach speed of vehicles, the junction geometry, the junction control and the land use are significant factors contributing to the occurrence of motorcycle crashes at junctions. Amelia and Harnen (2010) built a probability model to predict the motorcycle crash occurrence for the city of Malang in Indonesia and they suggested that gender (i.e. male riders), the increase of motorcycle ownership, long travel distances and little riding knowledge are factors that have a significant impact on the occurrence of motorcycle crashes. Manan et al. (2013) developed a safety performance function for fatal motorcycle crashes for primary roads and they suggested that an increase of traffic flow and number of access points per kilometer lead to an increase in motorcycle crash fatalities. However, it appears that to date there are no models developed to assess the effect of non-lane-based movement of motorcycle on crash occurrence. In addition, as most of the above models were built based on historical crash data, they inherit the drawback of poor data quality which is a major issue in most low-income and middle-income countries (Ismail, 2010; Laureshyn, 2010).

Although several researchers focused on investigating the effect of manoeuvre behaviour of motorcyclists on crash risk, they mainly focused on the conventional traffic environment of high-income countries where the passenger cars are the predominant vehicle types. For example, Elliot et al. (2006) using a questionnaire found that traffic errors, speed violations, stunts, safety equipment and control errors are significant factors relating to crash risk for motorcyclists. Pai and Saleh (2008) evaluated factors contributing to the severity level of motorcyclist injuries in sideswipe collisions between motorcycles and other motorised vehicles at T-junctions in the United Kingdom and they suggested that motorcyclist injuries are more severe when an overtaking motorcycle collides with a turning vehicle. Haque et al. (2009) examined the effect of roadway characteristics, environmental factors, motorcycle descriptions, and rider demographics on the fault of motorcyclists involved in crashes at intersections, expressways, and non-intersections and found that the higher the speed of motorcycles the higher likelihood of at-fault crashes on expressways.

Moreover, the International Road Assessment Programme (2009) developed a star rating protocol to assess the safety level for four road user groups including car occupants, motorcyclists, bicyclists and pedestrians. For motorcyclists, the star rating score is calculated for five crash types including run-off, head-on, intersection, property access and along crashes. Due to the range of paths that motorcycles can take within traffic streams, those five crash types are likely to capture less of the total motorcycles' crashes (Lynam, 2012). Sideswipe crashes and rear-end crashes away from intersections are found to account for a large proportion of total motorcycles' crashes in urban environments (AASHTO, 2009; Davoodi et al., 2011; DoT, 2013; Ming et al., 2013). However, these two crash types are not taken into account by the existing iRAP star rating score system (iRAP, 2013) which is based on research covering more conventional traffic composition and focusing mainly on inter-urban roads.

Therefore, the literature review seems to suggest that there is a lack of models focusing on evaluating the movement characteristics of motorcycles contributing to the risk of crashes in the traffic environment where the motorcycle is the predominant mode of transport. In addition there is a need therefore to obtain a surrogate measure to address the limitation of historical crash data analysis approach and to develop a methodology to capture crash potentials associated with motorcyclists' manoeuvre behaviour in the above conditions. The preliminary results of the proposed models may be used to support traffic engineers in improving urban road safety and developing appropriate countermeasures to mitigate the crash risk for motorcyclists. Furthermore, the proposed methodology is expected to

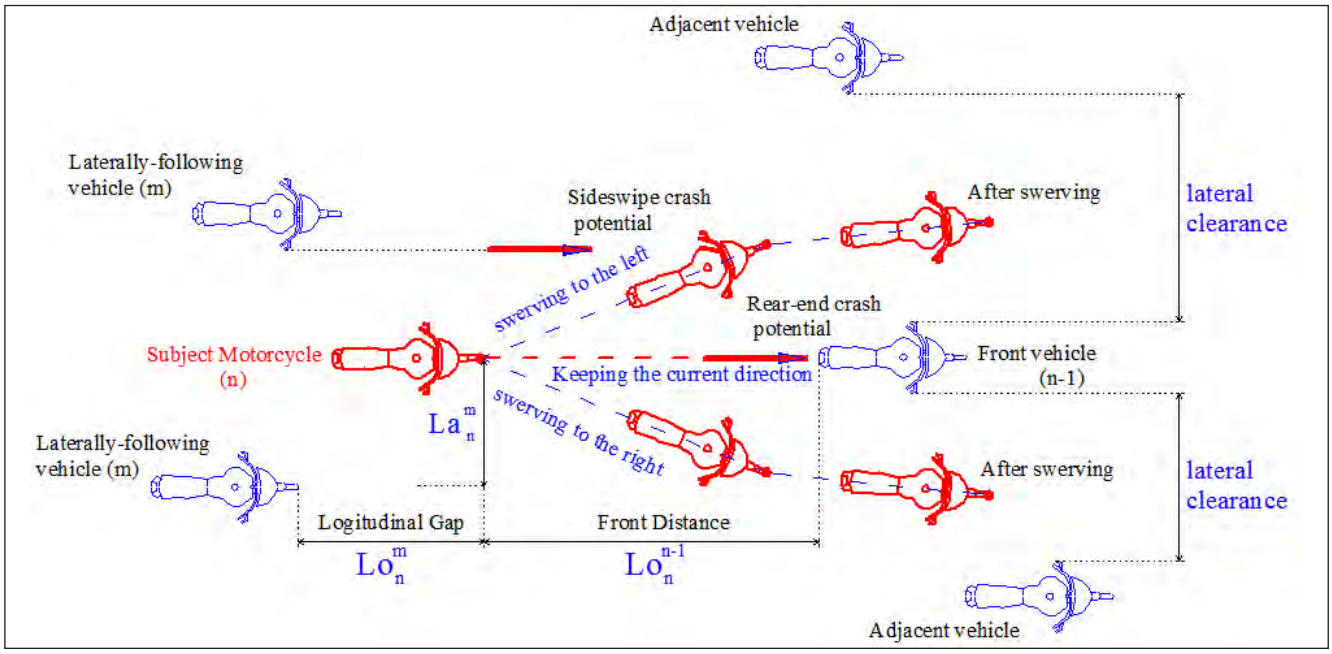

Figure 1. Movement scenarios of motorcycles in the traffic

provide a better understanding of the influence of non-lane-based movement characteristic of motorcycles on crash potentials, and to trigger further research on road safety assessment for motorcyclists in LMICs where motorcycles are the predominant mode of urban transport.

Methodology

The concept of non-lane-based movement

Due to their small size and flexible turning radius, motorcycles can manoeuvre relatively freely in the traffic stream. In a motorcycle-dominated traffic environment, motorcycles do not conform to lane disciplines and lane markings as passenger cars do. They tend to swerve to change their directions and speeds frequently. Also, because they occupy a small space when travelling, motorcycles are able to travel alongside other vehicles in the same lane as well as filter through the lateral clearance between vehicles. These movement characteristics are described to be as the non-lane-based movement characteristics of motorcycles (Minh, 2007; Lee, 2007; Long, 2012; Shiomi et al., 2013). Such non-lane-based movement characteristics are found to be the major causes contributing to the crash risk for motorcyclists (Hsu et al, 2003; Minh, 2007; Amelia and Harnen, 2010; Long, 2012; Manan, 2014).

Modelling framework

When travelling on roads, a motorcyclist has three choices for his/her manoeuvre: keep following the front vehicle, swerve to the left or swerve to the right to overtake the front vehicle as shown in Figure 1. When following the front vehicle, a rear-end crash may occur if the front vehicle suddenly decelerates while the subject motorcyclist maintains an inadequate distance that does not allow the subject motorcyclist to take an evasive action to avoid crashing with the front vehicle. When swerving to the left or the right, a sideswipe crash may occur if the available gap between the subject motorcycle and the laterally-following vehicle is less than the distance needed for the laterally-following vehicle to take evasive action to avoid crashing with the subject motorcycle. Using this assumption, to capture the potentials of these crash types for motorcycles moving in the traffic stream, a rear-end and a sideswipe crash risk model may be developed.

The crash risk is defined in this research as a conflict potentially leading to a crash if the motorcyclists involved in the conflict do not take evasive action properly. Under this assumption, two types of conflicts are considered in this study (See Figure 2).

- a rear-end conflict, occurring when a motorcyclist follows a front vehicle in a short distance that cannot allow the motorcyclist to apply a brake to avoid a potential rear-end crash with the front vehicle;
- a sideswipe conflict, occurring when a motorcyclist swerves to left or right and causes a potential sideswipe crash with the laterally-following vehicle.

To build model forms for describing rear-end and sideswipe crash risk, this study uses the logistic regression model and the lognormal distribution function. The former is adopted to capture the manoeuvre behaviour of motorcyclists potentially causing an interaction and the latter is employed to identify the occurrence of conflicts potentially resulting in crashes. The risk of a crash may be illustrated as the consequence of two independent events:

- the cause resulting in a potential conflict; and
- the condition in which the conflict may occur.

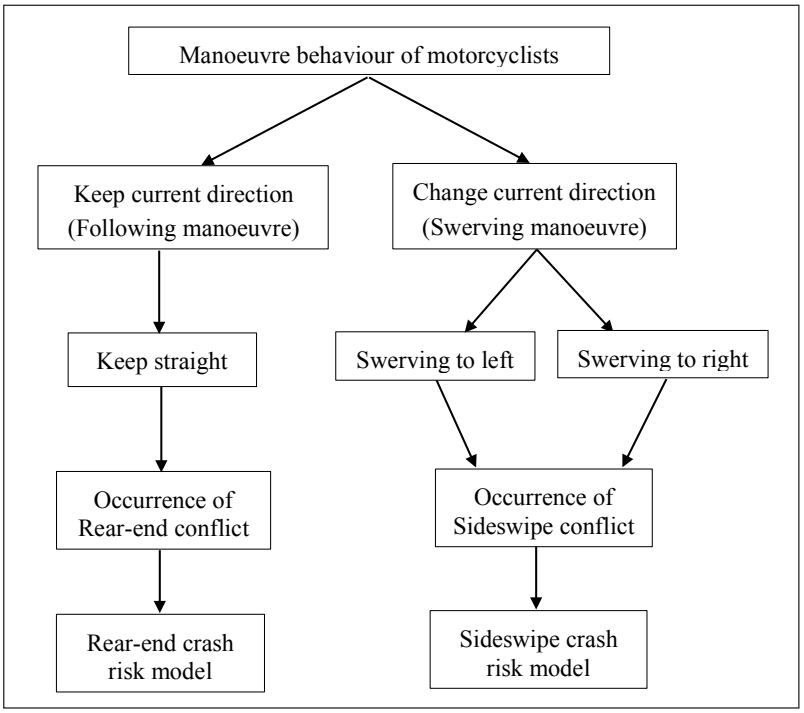

Figure 2. Modelling Framework

In the context of this study, the cause of a conflict is defined as the risky movement of the motorcycle and the condition for a conflict to occur is the inadequate gaps maintained between motorcycles. Therefore, the proposed crash risk models are formed by the joint probability:

- the probability of the causes leading to the conflict; and
- the probability of the condition resulting in the conflict occurrence.

Model Development

Rear-end crash risk model

The potential of a rear-end crash for a motorcycle (n) moving in a motorcycle-dominated traffic situation may be defined as the result of a series of events: (i) the subject motorcycle (n) keeps its current direction to follow the front vehicle (n-1) with a front distance ($Lo_{\mathrm{n}}^{\mathrm{n-1}}$); (ii) the front vehicle suddenly slows down; (iii) the subject motorcycle must decelerate to reduce its speed to avoid a possible rear-end crash with the front vehicle and (iv) a rear-end conflict occurs if the front distance is less than the threshold safety distance (D_{TSD}^{FM}) and it potentially leads to a rear-end crash if the motorcycles involved in the conflict do not take proper evasive action. Under the assumption that these events are independent, the probability that a rear-end crash may occur at a point of time t under a given traffic condition X (e.g. high traffic density) may be estimated by the joint probabilities of these events as follows:

$$Pr(RE_{n-1}^{n}) = Pr(FM_n|X) \times Pr(FM_{n-1}|X) \times Pr(C_n^{n-1}|D_{TSD}^{FM}) \quad (1)$$

where,

- $Pr(FM_n|X)$: is the probability that the subject motorcycle (n) will keep its current direction under a given traffic condition X;
- $Pr(FM_{n-1}|X)$: is the probability that the preceding vehicle (n-1) will keep its current direction under a given traffic condition X;
- $Pr(C_n^{n-1}|D_{TSD}^{FM})$: is the probability of occurring a rear-end conflict between the subject motorcycle (n) and the front vehicle (n-1).

Sideswipe crash risk model

The potential of a sideswipe crash for a motorcycle (n) moving in a motorcycle-dominated traffic situation may be defined as the result of a series of events: (i) the subject motorcycle (n) swerves to the left or right to overtake the front vehicle; (ii) the laterally-following vehicle (m) must decelerate to reduce its speed to avoid a possible sideswipe crash with the subject motorcycle and (iii) a sideswipe conflict occurs if the longitudinal gap (Lo_n^m) is less than the threshold safety distance (D_{TSD}^{SM}) and it potentially results in a sideswipe crash if the motorcycles involved in the conflict do not take proper evasive actions. Under the assumption that these events are independent, the possibility that a sideswipe crash may occur at a point of time t under a given traffic condition X (e.g. high traffic density) may be estimated by the joint probabilities of these events as follow:

$$Pr(SW_n^m) = Pr(SM_n|X) \times Pr(FM_m|X) \times Pr(C_n^m|D_{TSD}^{SM}) \quad (2)$$

where,

- $Pr(SM_n|X)$: is the probability that the subject motorcycle (n) will swerve to the left and right under a given traffic condition X;
- $Pr(FM_m|X)$: is probability that the laterally-following vehicle (m) will keep its current direction under a given traffic condition X;
- $Pr(C_n^m|D_{TSD}^{SM})$: is the probability of occurring a sideswipe conflict between the subject motorcycle and the laterally-following vehicle (m).

Model components

To fully implement the proposed estimation methodology in Equation (1) and (2), two probabilities should be calculated: (i) the probabilities that the motorcycle chooses either a swerving manoeuvre or a following manoeuvre to perform in a given traffic condition, and (ii) the probabilities that the conflicts occur between the subject motorcycle with the front vehicle or with the laterally-following vehicle when it performs a following or a swerving manoeuvre.

To capture the probability that the subject motorcycle chooses either swerving manoeuvre or following manoeuvre to perform in a given traffic condition, a manoeuvre choice model is developed based on the discrete choice analysis using the binary logistic regression model. The form of binary logistic regression model represents the probability that a motorcycle chooses a swerving manoeuvre behaviour as follows (Ben-Akiva and Lerman, 1985):

$$Pr(SW_n|X) = \frac{e^{g(x_i)}}{1 + e^{g(x_i)}} \quad (3)$$

The probability that a motorcycle chooses a following manoeuvre behaviour is given by:

$$Pr(KS_n|X) = 1 - Pr(SW_n|X) = 1 - \frac{e^{g(x_i)}}{1 + e^{g(x_i)}} = \frac{1}{1 + e^{g(x_i)}} \quad (4)$$

where, g(x) is the logit of the logistic regression model, x_i are independent variables affecting the choice of swerving manoeuvre behaviour of the subject motorcyclist.

It is felt that before deciding to choose a path to travel in a traffic stream, drivers normally evaluate the current driving conditions with respect to the relation with surrounding vehicles. In other words, the presence of neighbouring vehicles on the road directly affects the subject drivers' decisions for their movement choices. It therefore seems reasonable to suggest that the movement behaviour of the subject motorcyclist depends on the relative positions and relative speeds of the subject motorcycle with respect to its surrounding vehicles including: the relative speeds with the front vehicle (V_n^{n-1}), the relative distance with the front vehicle (Lo_n^{n-1}), the lateral clearance of the front vehicle (La_{n-1}), the relative speeds with the laterally-following vehicle (V_n^m), the longitudinal gaps with the laterally-following vehicle (Lo_n^m), the type of front vehicle (Te_{n-1}) and the type of laterally-following vehicle (Te_m). In a motorcycle dominated traffic environment, the type of front vehicle and laterally-following vehicle may be a motorcycle or a passenger car. Heavier vehicles such as buses or trucks were not considered in this study. These variables are illustrated in Figure 1.

Therefore, the logit of the logistic regression model $g(x_i)$ for the seven independent variables $x_i = (Lo_n^{n-1}, V_n^{n-1}, Lo_n^m, V_n^m, La_{n-1}, Te_{n-1}, Te_m)$ may be formulated as follows:

$$g(x_i) = \beta_0 + \beta_1 Lo_n^{n-1} + \beta_2 V_n^{n-1} + \beta_3 Lo_n^m + \beta_4 V_n^m + \beta_5 La_{n-1} + \beta_6 Te_{n-1} + \beta_7 Te_m \quad (5)$$

where, β_0, β_1, β_2, β_3, β_4, β_5, β_6, β_7 are unknown coefficients of independent variables to be estimated from the real data.

This paper defines traffic conflict as a condition of two consecutively moving motorcycles having inadequate threshold-safety-distance (TSD) such that the following motorcycle will crash into the front motorcycle when it swerves or makes an unexpected stop. The TSD indicators are calculated based on the stopping distance of a vehicle and identified separately for the rear-end conflict scenario (D_{TSD}^{SM}) and the sideswipe conflict scenario (D_{TSD}^{FM}) (see Appendix A). In a real traffic stream, the front distances (Lo_n^{n-1}) and the longitudinal gaps (Lo_n^m) are likely to follow a lognormal distribution (Minh, 2007; Lee, 2009). Therefore, the probability that the rear-end conflicts occur on a road segment may be predicted based on a lognormal distribution function as follows:

$$Pr(C_n^{n-1}|D_{TSD}^{FM}) = Pr(Lo_n^{n-1} \le D_{TSD}^{FM}) = \Phi\left[\frac{ln(D_{TSD}^{FM}) - \mu^{Lo_n^{n-1}}}{\sigma^{Lo_n^{n-1}}}\right] \quad (6)$$

where, $\Phi[\cdot]$ denotes the cumulative standard normal distribution, $\mu^{Lo_n^m}$ and $\sigma^{Lo_n^m}$ are the mean and standard deviation of the logarithm of front distances respectively.

Similarly, the probability that the sideswipe conflicts occur on a road segment is expressed by:

$$Pr(C_n^m|D_{TSD}^{SM}) = \Pr(Lo_n^m \le D_{TSD}^{SM}) = \Phi\left[\frac{\ln(D_{TSD}^{SM}) - \mu^{Lo_n^m}}{\sigma^{Lo_n^m}}\right] \quad (7)$$

where, $\Phi[\cdot]$ denotes the cumulative standard normal distribution, mean $\mu^{Lo_n^m}$ and $\sigma^{Lo_n^m}$ are the mean and standard deviation of the logarithm of longitudinal gaps respectively.

Model Specification and Verification

Data collection

To specify and verify the proposed model, a traffic survey was conducted on a road segment in the city of Danang in Vietnam. Vehicles' trajectory data was collected using video recording. A representative road segment of length 40 m and of width 7.0 m on the Nguyen Tri Phuong street was chosen that could be captured by the video camera (see Appendix B). The traffic survey was conducted on 20th August, 2014, from 6:00 am to 09:00 am and 3:00 pm to 6:00 pm.

Table 1. Estimated coefficients for the best fitting manoeuvre choice model

Variables		Estimated Parameters	Standard Error	Wald test	p-value
Front distance	Lo_n^{n-1}	-1.677	0.234	51.246	< 0.001
Speed of front vehicle	V_n^{n-1}	1.452	0.283	26.379	< 0.001
Longitudinal gap	Lo_n^m	0.139	0.056	6.161	0.013
Speed of laterally-following vehicle	V_n^m	0.224	0.109	4.196	0.041
Lateral clearance	La_{n-1}	1.445	0.193	56.020	< 0.001
Type of laterally-following vehicle	Te_m	-0.642	0.096	44.652	< 0.001
Constant		-0.524	0.591	0.785	0.376

Data extraction

The trajectories of vehicles were manually extracted from the recorded video file using the SEV (Speed Estimation from Video Data) computer software (Minh, 2007) which converts video screen coordinates into roadway coordinates. As a result, a data set containing 535 observations of the trajectories of 115 subject motorcycles and 2675 observations of 575 influential vehicles was used to estimate the unknown coefficients of the proposed models. The data set included flow density, relative positions, speeds, accelerations and decelerations of each vehicle.

Results and Discussions

Coefficient estimation

The statistical software SPSS was used to analyze the vehicle trajectory data and to estimate the unknown coefficients of independent variables. The Wald test revealed that the (Te_{n-1}) variable does not affect significantly on the swerving manoeuvre decision of motorcyclists and thus it was removed from the model. The final estimate results are summarized in Table 1 together with further statistical tests. As a result, the best fitting model capturing the probability that the motorcyclist chooses a swerving manoeuvre is expressed:

$$Pr(SM_n|X) = \frac{e^{-0.524-1.677Lo_n^{n-1}+1.452V_n^{n-1}+0.139Lo_n^m+0.224V_n^m+1.445La_{n-1}-0.642Te_m}}{1+e^{-0.524-1.677Lo_n^{n-1}+1.452V_n^{n-1}+0.139Lo_n^m+0.224V_n^m+1.445La_{n-1}-0.642Te_m}} \quad (8)$$

By considering the statistical tests shown in Table 1, it may be seen that the estimated coefficients of independent variables are statistically significant which means that the proposed model satisfactorily captures the swerving manoeuvre choice behaviour of motorcyclists in a motorcycle-dominated traffic situation.

Longitudinal gap and front distance distribution

The statistical characteristics of the longitudinal gaps and the front distances from the data set were investigated and it was found that these distances are correlated with the traffic density condition and may be fitted with a polynomial function as shown in Table 2. The Kolmogorov-Smirnov test (K-S test) measure was also applied to verify the assumption of the distribution for these distances and the results illustrate that they follow a lognormal distribution.

Therefore, Equation (6) and (7) become:

$$Pr(C_n^{n-1}|D_{TSD}^{FM}) = \Phi\left[\frac{ln(D_{TSD}^{FM}) - (7*10^{-5}\,Den^2 - 0.019Den + 2.108)}{0.52}\right] \quad (9)$$

$$Pr(C_n^m|D_{TSD}^{SM}) = \Phi\left[\frac{ln(D_{TSD}^{SM}) - (4*10^{-5}\,Den^2 - 0.013Den + 1.823)}{0.3}\right] \quad (10)$$

Sensitivity analysis

The effect of input variables on the outputs of the proposed models was tested. To simplify the process, several input variables were assumed to be a constant. The reaction time (τ) of the motorcyclists is 0.5 second (Minh, 2007), the braking deceleration of motorcycles in emergency situation is 6.02 m/s/s (Davoodi and Hamid, 2013), the swerving angle is 12.5 degree (the mean determined from the collected data set). Therefore, the effects of the following input data on the model was tested: Front distance; Longitudinal gap; Speed; Speed difference; Traffic density and Lateral clearance (see Appendix C).

Table 2. Statistical properties of longitudinal gaps and front distances

Factor	Lognormal distribution			K-S test
	Mean	R-squared value	Standard Deviation	Confidence
Front distance	$7*10^{-5}\,Den^2 - 0.019Den + 2.108$	0.75	0.52	0.51
Longitudinal gap	$4*10^{-5}\,Den^2 - 0.013Den + 1.823$	0.62	0.30	0.95

Den: is the traffic density defined as the number of motorcycles travelling on a road segment of length 100m and width 10m.

Table 3. Comparison results between predicted and observed conflict frequency

Time periods	Predicted conflicts			Observed conflicts			Percentage correct (+/- %)
	Rear-end	Sideswipe	Total	Rear-end	Sideswipe	Total	
6:00am-7:00am	7.4	3.6	11.0	9	5	14	78.5
7:00am-8:00am	32.7	8.1	40.8	27	10	37	89.8
8:00am-9:00am	19.6	11.8	31.4	24	14	38	82.6
3:00pm-4:00pm	4.1	1.7	5.8	5	2	7	83.0
4:00pm-5:00pm	18.6	8.8	27.3	22	12	34	80.4
5:00pm-6:00pm	57.3	12.9	70.2	46	15	61	84.9

Model verification

The main purpose of the field validation task was to verify the performance of the proposed models in the real-world by comparing the predictive conflict frequency produced by the proposed models with the actual conflict frequency observed in the field. This verification task is conducted in two steps. First, rear-end conflict and sideswipe conflict frequencies are observed in the field for different time periods in a day in order to fully capture conflict frequencies for both peak hours and non-peak hours. Second, the frequencies of rear-end and sideswipe conflicts are predicted using the proposed models for those same time periods and then the estimate results are compared with the real observed conflict frequencies in the field by determining the percentage correct of estimate with observed values. The data used for this field verification was collected on a road segment of length 40.0 m and of width 7.5 m on Truong Chinh street. The comparison results for each hour of six hours from 6:00 am to 9:00 am and from 3:00 pm to 6:00 pm are presented in Table 3 and show a good degree of accuracy between predicted and observed conditions. It is appreciated however that a more extensive trial programme could lead to a calibrated model.

Model Applications

The rear-end and sideswipe crash risk models developed in this study may support traffic engineers in detecting hazardous traffic locations associated with higher crash potentials and assessing their contributing risk factors with the aim to develop appropriate countermeasures to mitigate the crash risk for motorcyclists. In addition, other potential applications of the developed models such as developing a new concept of Conflict Modification Factor (CoMF) and enhancing the existing International Road Assessment Programme (iRAP) methodology as presented in the following sections.

The Development of Conflict Modification Factor (CoMF)

To address specific safety concerns of a specific location on road networks, a treatment should be determined and implemented. To estimate the effectiveness of a treatment, Crash Modification Factor (CMF) is used as a tool to support this effort. CMF is used to estimate crash frequency or the change in crashes due to the implementation of a given countermeasure at a specific location by multiplying a CMF with the number of crashes before applying a treatment to estimate the number of crashes after applying a treatment (AASHTO, 2009; Gross et al., 2010).

In low-income and middle-income countries, obtaining reliable crash data to define CMFs is a difficult task due to the under-reporting of crashes and the poor quality of historical crash data (Lynam, 2012). Therefore, this study proposes a concept of Conflict Modification Factor (CoMF) and as potential surrogate measure to CMF in road safety assessment due to the following reasons:

- The causal mechanism for conflicts and crashes are similar (Hyden, 1987; Svensson, 1998; Guo et al., 2010). According to Laureshyn (2010), the occurrence of a crash is always proceeded by a conflict;
- There is statistical relationship between the frequency of conflict and crash events (Amundsen and Hydén, 1977; Miglez, Glauz and Bauer, 1985; Hydén, 1987; Svensson, 1992; Archer, 2004; Gettman *et al.,* 2008; HSM, 2009; Ismail, 2010; Laureshyn, 2010; Guo *et al.,* 2010). Gettman *et al.* (2008) found that the ratio of traffic conflicts to actual crashes may be 20,000 to 1;
- The effects of contributing factors on the occurrence of conflicts and crashes do not seem to be different (Guo *et al.,* 2010).

CoMFs are defined as the ratio of the likelihood of conflicts for a specific location under a specific condition to the likelihood of conflicts for the same location under a base

Table 4. Risk factors contributing to the Likelihood and Severity of rear-end and sideswipe crash types

Crash type	Risk factors contributing to the Likelihood	Risk factors contributing to the Severity
Rear-end	Speed Speed difference Traffic density Front distance Lateral clearance Road surface condition Presence of segregated motorcycle lane	Speed Presence of heavier vehicles Segregated motorcycle lane
Sideswipe	Speed Speed difference Traffic density Longitudinal gap Lateral gap Road surface condition Presence of segregated motorcycle lane	Speed Presence of heavier vehicles Segregated motorcycle lane

condition. According to this definition, CoMFs of risk factors may be used as the relative risk values presenting the changes in crash potentials due to the change in values of those risk factors.

To this end, CoMFs are developed in this study as follows. Using the theory of probabilities, the likelihood of event occurrence is defined as the ratio of the probability of event occurrence to the probability of event non-occurrence (Guo et al., 2010). Therefore, the likelihood of conflict occurrence may be defined as follows:

$$likelyhood\ of\ conflict = \frac{probability\ of\ event\ occurrence}{probability\ of\ event\ nonoccurrence} \quad (11)$$

$$Conflict\ Modification\ Factor = \frac{likelyhood\ of\ conflict_{certain\ traffic\ conditions}}{likelyhood\ of\ conflict_{baseline\ traffic\ condition}} \quad (12)$$

The proposed CoMFs represent the relative change in the conflict frequency due to the change in one specific condition while all other conditions remain constant. Subsequently, the CoMFs may be calculated as follows:

The baseline traffic condition is defined as the normal driving condition in which motorcyclists can move freely in the traffic stream with a low crash risk level. As a result, for the proposed crash risk models, CoMFs are developed for its variables (i.e. traffic density, operating speed, speed difference, front distance, longitudinal gap, lateral clearance, lateral gap, road surface condition, separate motorcycle lane, presence of heavier vehicles) based on the sensitivity analysis of section 3.4. The relative risk values (CoMFs) of these variables are presented in Appendix D.

Enhancing the existing iRAP star rating system for motorcyclists

Methodology

The International Road Assessment Programme (iRAP) has developed a Star Rating methodology to assess and improve the safety of roads in the low-income and middle-income countries (iRAP methodology, 2013). It is based on the assessment of infrastructure attributes to identify the likelihood of a crash and its severity. For motorcyclists, the star rating score is based on assessing five crash types including run-off crash, head-on crash, intersection crash, property access crash, and along crash. These are likely to capture less of the total motorcycles' crashes in urban environments (Lynam, 2012). The existing star rating score (SRS) is calculated as follows:

Motorcyclist SRS = (Run-off + Head-on + Intersection + Property + Along) Crash Scores

Therefore, to provide an enhanced tool for assessing the motorcyclist safety in a motorcycle-dominated traffic environment, the existing star rating score system of the current iRAP methodology may be enhanced by taking into account the risk of rear-end and sideswipe crashes as follows:

Enhanced Motorcyclist SRS = (Run-off + Head-on + Intersection + Property + Along + Rear-end + Sideswipe) Crash Scores (13)

The scores of rear-end and sideswipe crashes are calculated as follows:

(Rear-end / Sideswipe) Crash Score = Likelihood x Severity x Operating speed x External flow influence (14)

where,

- Likelihood refers to risk factors that account for the chance that a crash will be initiated;
- Severity refers to risk factors that account for the severity of a crash;
- Operating speed refers to factors that account for the degree to which risk changes with speed;
- External flow influence factors account for the degree to which a person's risk of being involved in a crash is a function of another person's use of the road.

The risk factors that contribute to the likelihood and severity of rear-end and sideswipe crashes are shown in Table 4.

Table 5. Comparison results between existing and enhanced iRAP star rating system

Location	Existing iRAP Star Rating system		Enhanced iRAP Star Rating system	
	SRS	Rating star	SRS	Rating star
1	0.76	5-star	2.9	4-star
2	0.76	5-star	2.2	5-star
3	0.76	5-star	2.6	4-star
4	0.76	5-star	3.3	4-star
5	0.76	5-star	3.5	4-star

In the iRAP methodology, the relative risk values of the above factors are known as Crash Modification Factors (CMFs) (iRAP methodology, 2013). In a similar and simplified manner, the scores of rear-end crash type and sideswipe crashes are associated with the CoMF which are based on potential conflicts instead of actual crashes. In other words, CMF represents the relative change in the crash frequency due to the change in one specific risk factor and CoMF represents the relative change in the conflict frequency due to the change in one specific risk factor.

Comparison

Comparative test to the existing iRAP methodology

To compare the outputs between the existing iRAP star rating system and the enhanced iRAP star rating system, real data was collected from five homogeneous road sections chosen from five divided roads in the city of Danang in Vietnam and then analyzed (see Appendix E). The results (see Table 5) show that the existing iRAP star rating system produces the same Star Rating Score (SRS) for all locations, implying that all these locations have the same risk. However, the actual historical crash data of these locations are different and they present the same trend with the SRS produced by the enhanced iRAP star rating methodology.

Comparative test to the HSM methodology and actual historical crash

The above was tested further first by calculating the average yearly crash frequency for each road segment as proposed by AASHTO's Highway Safety Manual (HSM) (2009). These locations were then ranked based on the predicted average yearly crash frequency in descending order. The same locations were ranked based on the enhanced iRAP star ratings and based on the average yearly actual crash frequency (real crash data collected from Da Nang Department of Police over the period from 2008 to 2015) and then by using the Spearman rank correlation coefficient the three rankings were compared.

The outputs of methodologies and the corresponding rankings for locations are shown in Table 6 and the Spearman correlation coefficients are shown in Table 7. The comparison results reveal that there is a strong correlation between the outputs of the enhanced iRAP star rating methodology with the actual historical crash data, implying that the enhanced iRAP methodology produce most satisfactory results.

Conclusion

The paper presented a methodology to estimate the rear-end and sideswipe crash risk for motorcyclists in a motorcycle-dominated traffic environment of urban roads. The innovative feature of the methodology is the non-lane-based movements of motorcycle are captured to evaluate their contribution to the crash risk. In addition, a new concept of the Conflict Modification Factor (CoMF) was proposed as a potential surrogate measure to Crash Modification Factor (CMF) in determining the relative risk values of factors contributing to crashes and a methodology to integrate the developed models with the existing iRAP star rating system was also presented in the paper. The innovation of CoMFs is that they can be determined by using conflict

Table 6. Outputs of methodologies and rankings for road segments

Location	Enhanced iRAP methodology		HSM methodology		Actual historical crash	
	SRS	Ranking	Crash frequency	Ranking	Crash frequency	Ranking
1	2.9	3	0.6	2	3.3	3
2	2.2	5	0.4	5	1.4	5
3	2.6	4	0.5	4	2.5	4
4	3.3	2	0.6	3	4.2	2
5	3.5	1	0.8	1	5.5	1

Table 7. Spearman rank correlation coefficient

Methodology	Average actual historical crash
Enhanced iRAP SRS	1.00**
HSM methodology	0.97**

** Correlation is significant at the 0.01 level

frequency data instead of historical crash data required by conventional methodologies. The usefulness of CoMF is that it can be used to assess the effectiveness of a particular countermeasure by observing the conflicts in a short period of time to enable comparisons before and after implementing a particular countermeasure instead of waiting for sufficient years of crash data to build up. Furthermore, the study focused on the contribution of infrastructure factors and traffic conditions to the potential of motorcycle crashes. Other contributing factors that may affect motorcyclists' crash risk may include their knowledge and experience, alcohol or drugs consumption, and motorcycle capabilities but these were not included in the proposed models as in most cases this information cannot be directly measured from vehicles' trajectory data in real time.

In conclusion:

a) The developed methodology provides a good estimate of both the rear-end crash and sideswipe crash risks for motorcyclists in a motorcycle-dominated traffic environment of urban roads.

b) The front distance, the longitudinal gap, the lateral gap, the lateral clearance, speed difference, and the speed of motorcycles were found to be the predominant factors contributing to the rear-end and sideswipe crash risk.

c) The models may estimate the rear-end and sideswipe crash risk for motorcyclists using real time data; this could be an invaluable tool in detecting hazardous roads in traffic conditions where motorcycles is the predominant mode of transport.

d) A Conflict Modification Factor (CoMF) was proposed in this study as a surrogate measure to Crash Modification Factor for road safety assessment in order to overcome the under-reporting or unavailability of historical crash data in low-income and middle-income countries.

e) The proposed methodology to enhance the current iRAP star rating system seems to produce reliable results and subject to more testing, may be considered for full implementation.

f) The proposed models may assist traffic engineers in detecting hazardous locations associated with higher motorcycles' crash risk and developing appropriate countermeasures to improve motorcyclist safety.

Future works

The developed models in this study presented limitations associated with the data collection process and the variables included in the models. Therefore it is felt that future research may address the following aspects:

a) The effect of the frequency and distances between major road intersections on the manoeuvre behaviour of motorcyclists and their contributions to crash risk.

b) The effect of roadside activities (e.g. shopping centres, the presence of schools and office buildings, land uses) and parking lots on the manoeuvre behaviour of motorcyclists and their influence on crash potentials.

c) The effect of lighting, visibility and weather conditions on the manoeuvre behaviour of motorcyclists and the contribution of these factors to the crash frequency and severity.

e) The effect of motorcyclists' characteristics such as ages, gender, knowledge and driving experience on their behaviour and on crash frequency and severity.

f) The use of a wider and possibly more representative data set collected from various cities and countries with similar traffic characteristics to those considered in this study to calibrate the developed models.

Acknowledgements

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Appendix A

Threshold-safety-distance calculation

With regard to rear-end conflict scenario as illustrated in Figure A1, it is assumed that the front vehicle (n-1) suddenly decelerates to slow down and the subject motorcycle (n) responds to this urgent situation by applying the brake to avoid a possible crash. The threshold-safety-distance of this scenario is defined as the distance that the subject motorcycle needs to stop to avoid a possible crash with the front vehicle. This distance may be calculated as:

$$D_{TSD}^{FM} = v_n\tau_n + \frac{v_n^2}{2a_n} - \frac{v_{n-1}^2}{2a_{n-1}} \quad (A.1)$$

where, D_{TSD}^{FM} is the threshold-safety-distance for rear-end conflict scenario; tn, vn and an are the reaction time, initial speed and braking deceleration of the subject motorcycle respectively; vn-1 and an-1 are initial speed and braking deceleration of the front vehicle respectively.

With regard to sideswipe conflict scenario, it is assumed that the trajectory of the subject motorcycle (n) is the hypotenuse of a right triangle as illustrated in Figure A2 and the adjacent-following vehicle (m) starts braking while the subject motorcycle starts swerving. The threshold-safety-distance of this scenario is defined as the distance that the vehicle (m) needs to stop to avoid a possible collision while the motorcycle (n) executes a swerving manoeuvre. This distance may be calculated as:

$$D_{TSD}^{SM} = v_m\tau_m + \frac{v_m^2}{2a_m} - \frac{La_n^m \times cos\alpha_n}{sin\alpha_n} \quad (A.2)$$

where, is the threshold-safety-distance for sideswipe conflict scenario; τ_m, v_m and a_m are the reaction time, initial speed and braking deceleration of vehicle (m) respectively, is the initial lateral gap between motorcycle (n) and vehicle (m), and α_n is the swerving angle of motorcycle (n).

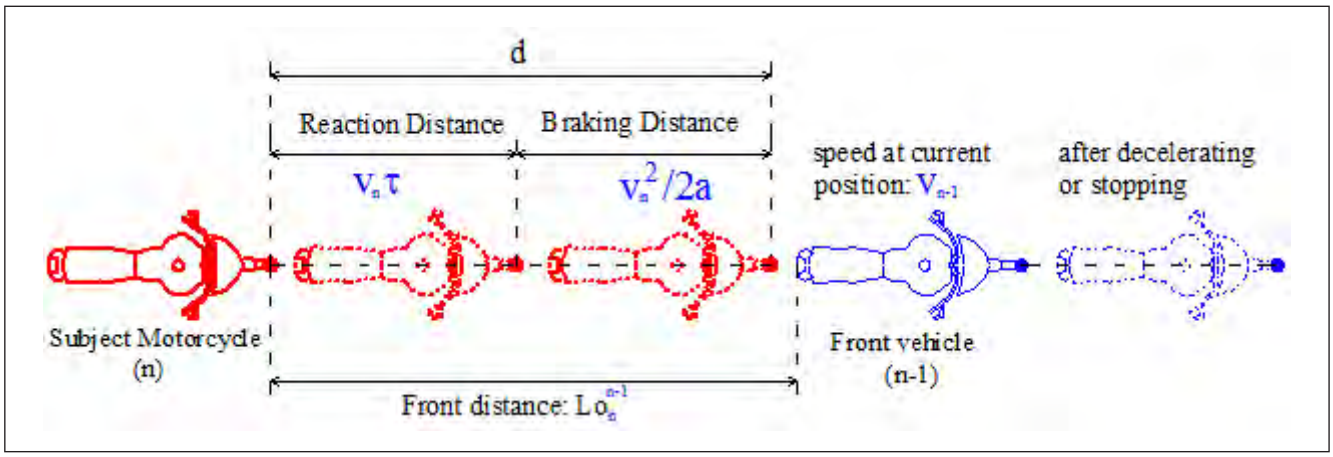

Figure A1. Rear-end conflict scenario

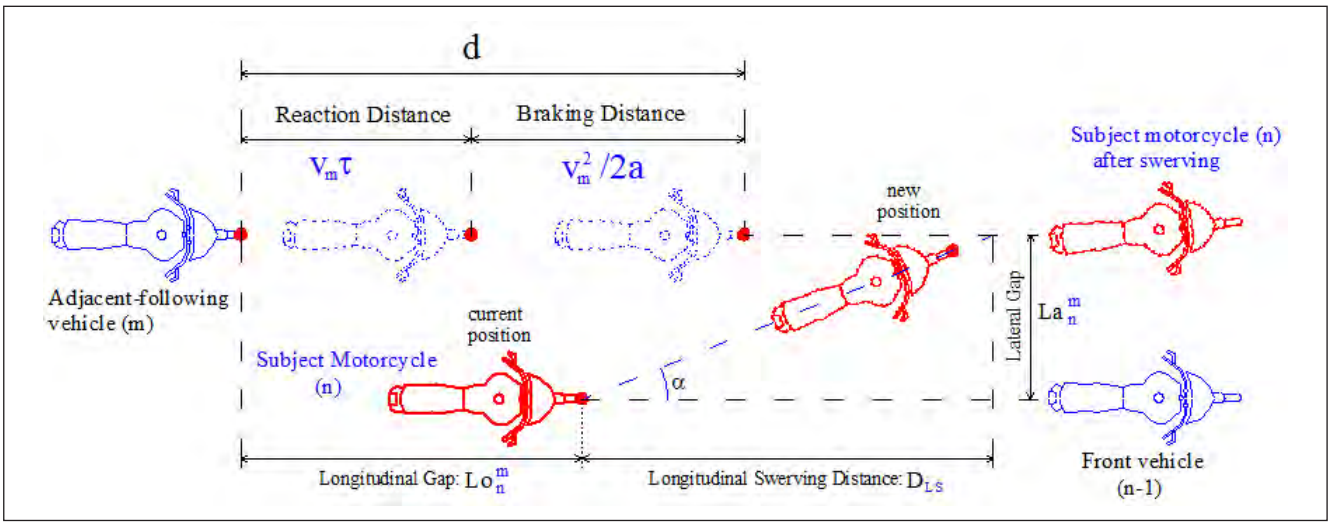

Figure A2. Sideswipe conflict scenario

Appendix B

The selected road segment for traffic survey

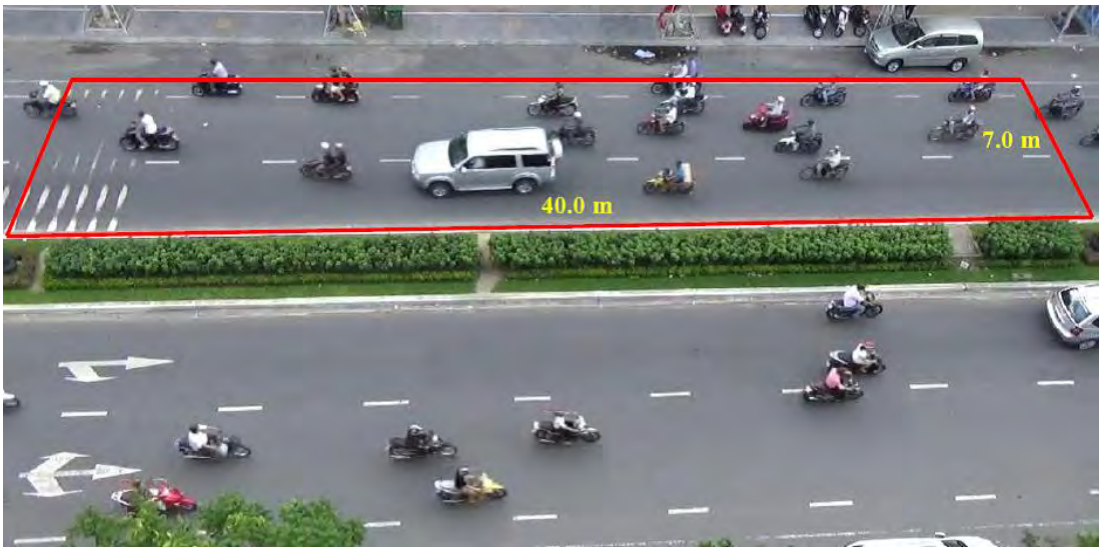

Figure B. The selected road segment for traffic survey

Appendix C

Sensitivity analysis results

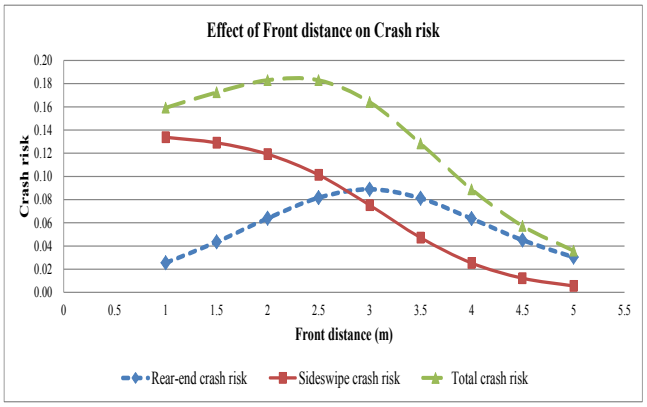

Figure C.1. Effect of front distance on crash risk

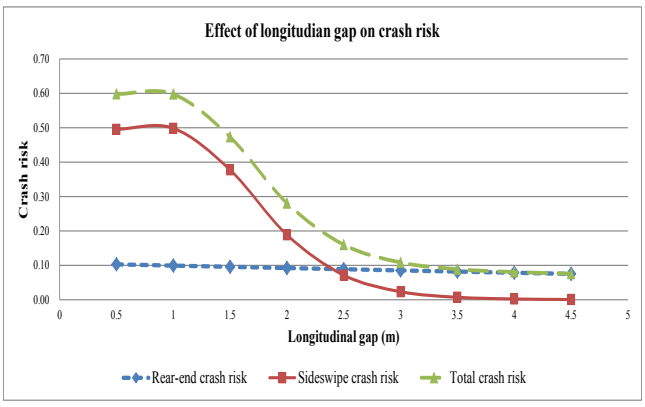

Figure C.2. Effect of longitudinal gap on crash risk

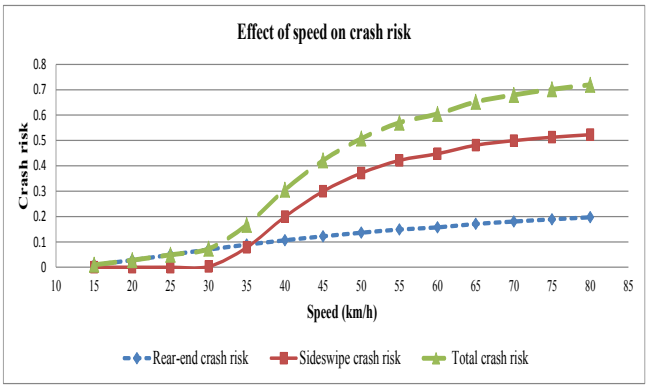

Figure C.3. Effect of speed on crash risk

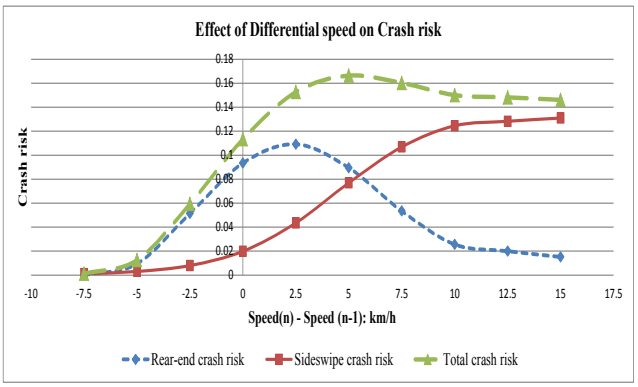

Figure C.4. Effect of speed difference on crash risk

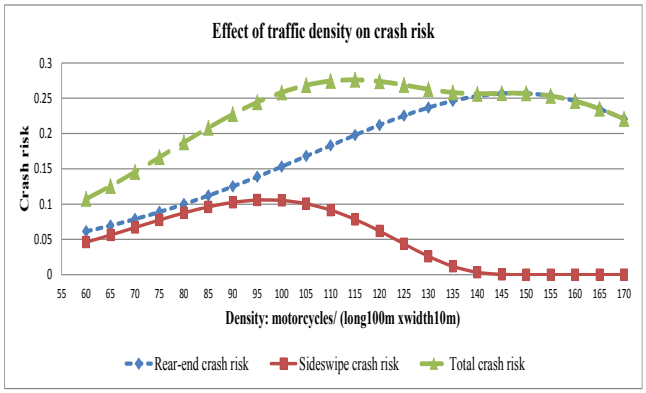

Figure C.5. Effect of traffic density on crash risk

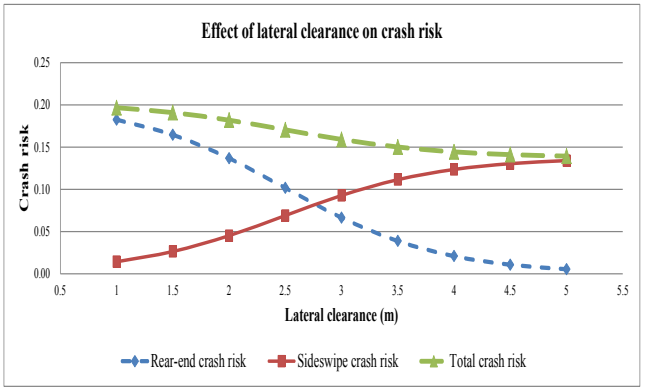

Figure C.6. Effect of lateral clearanc

Appendix D

Relative risk values of risk factors

Table D1. Relative risk values of front distance factor

Front distance (m)	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Rear-end crash	0.5	0.8	1.0	1.1	1.0	0.8	0.5	0.4
Sideswipe crash	3.0	2.7	2.3	1.6	1.0	0.5	0.2	0.1

Table D2. Relative risk values of speed difference factor

Speed difference (km/h)	-7.5	-5.0	-2.5	0.0	2.5	5.0	7.5	10.0	12.5	15.0
Rear-end crash	0.01	0.1	0.5	1.0	1.2	1.0	0.5	0.3	0.2	0.1
Sideswipe crash	0.1	0.1	0.4	1.0	2.2	4.1	5.9	7.0	7.3	7.4

Table D3. Relative risk values of longitudinal gap factor

Longitudinal gap (m)	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
Rear-end crash	1.1	1.1	1.0	1.0	1.0	0.9	0.9	0.8
Sideswipe crash	12.9	7.9	3.0	1.0	0.3	0.1	0.01	0.01

Table D4. Relative risk values of lateral clearance factor

Lateral clearance (m)	1.5	2.0	2.5	3.0	3.5	4.0	4.5
Rear-end crash	2.8	2.2	1.6	1.0	0.6	0.3	0.2
Sideswipe crash	0.3	0.5	0.7	1.0	1.2	1.4	1.5

Table D5. Relative risk values of speed factor

Speed (km/h)	25	30	35	40	45	50	55	60	65	70
Rear-end crash	0.5	0.8	1.0	1.2	1.4	1.6	1.8	1.9	2.1	2.3
Sideswipe crash	0.0	0.1	1.0	2.9	5.0	7.0	8.6	9.6	10.9	11.8

Table D6. Relative risk values of traffic density factor

Traffic density	Free flow	Few restriction	Low restriction	Moderate restriction	High restriction	Very high restriction
Rear-end crash	0.75	1.0	2.0	3.0	3.5	2.5
Sideswipe crash	0.75	1.25	1.5	0.5	0.25	0.1

Table D7. Relative risk values of lateral gap factor

Lateral gap (m)	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
Rear-end crash	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
Sideswipe crash	2.4	1.0	0.1	0.0	0.0	0.01	0.01	0.01

Table D8. Relative risk values for road surface condition factor

Road surface condition	Dry Pavement	Wet Pavement
Rear-end crash	1.00	1.1
Sideswipe crash	1.00	1.7

Table D9. Relative risk values of vehicle factor

Vehicle factor	Motorcycle	Heavier vehicle
Rear-end crash	1.00	1.5
Sideswipe crash	1.00	2.3

Table D10. Relative risk values of motorcycle lane presence

Separate motorcycle lane	Absence	Presence
Rear-end crash	1.00	0.66
Sideswipe crash	1.00	0.43

Appendix E

Traffic characteristics of road segments and historical crash data

The selected road segments for conducting traffic surveys were chosen in such a manner so that the following criteria could be satisfied:

- The traffic volumes should be large enough in order to be capable of capturing the movement behaviour of the subject motorcycles and their interactions between the subject motorcycles with other influential vehicles.
- There should be no bus stops, parking lots and intersections near the sites in order to capture discrete movements of vehicles and to avoid behaviour of road users affected by these road features.
- There should be normal driving conditions with clear weather, a dry pavement, low wind and un congested traffic flows.

Table E. Traffic characteristics of road segments and historical crash data

Location	Volume (vehicles/ day)	Density (vehicles/1000m^2)	Average speed (m/s)	Crash records (2008-2015)	
				Rear-end	Sideswipe
1	59704	89	9.68	21	5
2	41621	68	9.99	9	2
3	49706	72	9.83	16	4
4	61402	94	9.48	27	7
5	78945	76	9.19	35	9

Historical crash data collection source: Danang Department of Transport

Appendix F

Non-lane based movement characteristics of motorcycles

Due to their small size and flexible turning radius, motorcycles can manoeuvre relatively freely in the traffic stream. In a motorcycle-dominated traffic environment, motorcycles do not conform to lane disciplines and lane markings as passenger cars do. They tend to swerve to change their directions and speeds frequently. Also, because they occupy a small space when travelling, motorcycles are able to travel alongside with other vehicles in the same lane as well as filter through the lateral clearance between vehicles. These movement characteristics are described to be as the non-lane-based movement characteristics of motorcycles (Minh, 2007; Lee, 2007; Long, 2012; Shiomi et al., 2013). Such non-lane-based movement characteristics (e.g. Alongside manoeuvre, Oblique following manoeuvre, Filtering manoeuvre, Swerving/Weaving manoeuvre) were discussed in a number of previous studies as follows:

Alongside manoeuvre

Due to small size with the average width of 0.75 m which accounts for only 25 per cent of an average car-lane of 3.0 m, motorcycles occupy a small space while moving on roads and they are therefore capable of travelling alongside with other motorcycles in the same car-lane (Hsu et al., 2003; Minh, 2007; Lee, 2007; Long, 2012). Minh (2007) also described this behaviour as a pair-riding manoeuvre of motorcycles and it is commonly observable in a motorcycle-dominated traffic environment.

Oblique following maneuver

Due to a flexible movement characteristic, motorcycles can follow the preceding vehicle at an oblique position (Lee, 2007; Long, 2012). For this manoeuvre behaviour, motorcyclists can achieve a better view in front of and a better chance to overtake the front vehicle.

Filtering maneuver

Due to a small size and a flexible turning radius, motorcycles can move freely in the traffic stream. The filtering manoeuvre refers to the behaviour that a motorcycle moves through the lateral clearance between vehicles to achieve a desired speed and a better condition (Elliott et al., 2003; Minh, 2007; Lee, 2007; Long 2012). Minh (2007) described this behaviour as a zigzag movement of motorcycles and they tend to perform this manoeuvre frequently in a motorcycle-dominated traffic environment.

Swerving/weaving manoeuvre

Due to a small turning radius, motorcycles can make turns easily. The swerving manoeuvre refers to the behaviour that a motorcycle changes its current direction to move to the left or right beside the front vehicle. It may be sometimes followed by an overtaking or filtering movement. This is the typical behaviour that represents the none-lane-based movement characteristic of motorcycles and can be frequently observable in motorcycle-dominated traffic environments (Minh, 2007; Lee, 2007; Long, 2012).

Contributed articles

Letter to the Editors

It is time to consider a presumed liability law that protects cyclists and other vulnerable road users

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The contribution of Boufous, S. (2017), It is time to consider a presumed liability law that protects cyclists and other vulnerable road users, *Journal of the Australasian College of Road Safety*, *28*(4), 65-67, provides a thoughtful commentary on what is clearly a pressing need to provide a road traffic system that is safe for all road users and encourages healthy and sustainable modes. The author provides a case for the introduction of strict civil liability laws to encourage drivers to take more care to avoid cyclists, in turn providing a more fair and safe environment for cyclists.

Arising from this paper, there are two questions to be considered: one practical and the other ethical.

The practical question is whether the change will make a difference. The author provides evidence that strict liability will improve driver behaviour by reference to two studies. A paper from the United States (Maker, 2015) refers to experience in a number of European jurisdictions. The paper provides counter arguments, including a statement that many in the Netherlands are not aware of their liability laws (Maker 2015, p488) but couches these arguments as being promoted by "skeptics" or "critics". Maker concludes that strict liability *"...would create safer roads for cyclists."* (Ibid, p505). However, this conclusion appears to be based on subjective judgements such as: *"Even the automobile driver who does not care about the safety of the cyclist will surely care about the impact on his wallet"* (Ibid, p502) and comparisons with the application of strict liability for defective products – a quite different behavioural and organisational context. The second paper (Pucher & Buehler, 2008) examines the factors encouraging safer cycling in a number of European countries. It concludes that *"... the key to achieving high levels of cycling appears to be the provision of separate cycling facilities along heavily travelled roads and at intersections, combined with traffic calming of most residential neighbourhoods"*.

Against this limited evidence, one needs to consider the extensive body of understanding that is the basis of traffic enforcement systems. As described by authors such as Elliott (2008), deterrent theory suggests effectiveness is largely dependent on certainty of punishment. This is the basis of enforcement regimes that replace the unlikely, but high, cost arising from a crash with the far more certain, but lower, cost arising from a traffic infringement. In considering strict liability applied to crashes with cyclists, these will be unlikely events with the majority of motorists' transgressions remaining undeterred as they will not result in a crash. The effect is rendered even more uncertain if the impact of insurance is taken into account. Third party injury coverage is universal, property damage common (mandatory in The Netherlands). So, even if drivers overcome their optimism bias to remain concerned about the risk of a crash, the economic consequences will be slight.

The second, ethical, issue goes to the heart of the Safe System. As noted by Boufous, there is a need for equitable access to compensation for damage. In a civilised society, the strong have an obligation to protect the vulnerable. However, do strict liability laws strengthen the paradigm of blaming the driver when this is one of the key challenges in implementing the Safe System that most jurisdictions still struggle with? Should liability be determined against a human driver who has made momentary mistake, or against the system designers or operators who have allowed, and continue to allow, the conflict to occur? The latter would certainly encourage significant change.

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Transport Reviews, 28(4): 495-528.

Response: It is time to consider a presumed liability law that protects cyclists and other vulnerable road users

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The author would like to thank James Holgate for the interest in the paper. The two points raised are relevant and important to the debate over the potential role of presumed liability laws in protecting cyclists and other vulnerable road users.

It is difficult to provide reliable evidence regarding the first issue of whether the change in strict liability laws will make a difference, particularly in terms of reduced injury to cyclists. The main reason is that presumed liability laws were often implemented in some European countries at the same time as other measures, including better infrastructure and reduced speed limits in residential areas. The package of these measures, including presumed liability laws, has been attributed to improved cycling safety in these countries. As a minimum, changes in liability laws as proposed in the paper have the potential to raise awareness about the dangers facing cyclists on the road and to highlight the fact that motor vehicles are potentially "dangerous weapons" that requires caution, particularly around vulnerable road users, including pedestrians and cyclists.

On the second ethical issue of how the proposed changes to presumed liability laws fit within the wider context of safe system, I don't believe that the proposed changes necessarily strengthen the paradigm of blaming the driver. As mentioned, the changes will ensure equitable access to compensation for damage. In addition, while safe system approach to road safety accepts that human error is inevitable, it also recognises the need for responsible road user behaviour, which includes the responsibility of drivers as the "more powerful road users" towards vulnerable road users. At the same time, there is a need for improvements in the road transport system that makes allowances for errors by drivers and that minimises the consequences on vulnerable road users. These include what was mentioned at the end of the paper regarding the need for traffic calming with an emphasis on reduced speed limits in residential areas and better cycling infrastructure with appropriate intersection treatments.

Road Safety Policy & Practice

Telematics and Vehicle Safety

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Key Findings

- Pay-how-you-drive (PHYD) technology is available and is easily retro-fitted to vehicles
- The system typically monitors speed, deceleration, acceleration and cornering
- Drivers receive insurance premium discounts for complying with speed limits and minimising high acceleration/ deceleration events
- Substantial reductions in crashes are being reported

Abstract

Recent developments in telematics technology provide the opportunity to improve driver behaviour by rewarding good driving. Vehicle insurance companies in Europe and North America have successfully introduced pay-how-you-drive (PHYD) insurance policies where the driver agrees to have a telematics device installed in their vehicle in return for substantial reductions in insurance premiums. This paper describes recent developments with in-vehicle telematics, including incentives to encourage drivers to reduce risky driving behaviour. The potential road safety benefits are examined and some implementation issues are addressed. In-vehicle telematics is considered to be a promising vehicle safety technology, which can be easily retrofitted to existing vehicles.

Keywords

Telematics, driver behaviour, insurance, speeding

Introduction

In-vehicle recording of vehicle parameters such as location and speed, and transmitting this information to a remote monitoring system have been in use for decades. It is an essential component of Intelligent Transport Systems (ITS). This has mainly been used for commercial vehicle operations such as logistics, efficiency monitoring and incident tracking.

In recent years the data collected have been enhanced to include longitudinal acceleration (acceleration and braking) and lateral acceleration (cornering). Improvements to global positioning systems (GPS) have also brought greater accuracy in measuring vehicle speed (better than 1km/h accuracy). Digital mapping of roads has provided information on posted speed limits including differentiation of time activated speed zones (e.g. school zones). For example, in 2016 Transport NSW released the free "Speed Advisor" app for smartphones, giving drivers speed limit assistance throughout New South Wales (TNSW, 2016). In Europe mapping of speed limits is well-advanced, due partly to safety ratings by Euro NCAP which reward vehicles with speed limit advisory systems (Global NCAP, 2017).

Furthermore, data can now be readily transmitted through the mobile phone network in real time.

With these developments it is now possible to detect and record the following events, which might be associated with risk-taking:

- Excessive heavy braking events (distracted driver, inappropriate speed, following too closely, aggressive driving)
- Excessive high acceleration events (aggressive driving)
- Excessive cornering forces (inappropriate speed, aggressive driving)
- Time-of-day and geographic location (driving at high-risk times and/or locations)
- Exceeding the speed limit (inappropriate or dangerous speed, distracted, fatigued or inattentive driver)

There are various ways in which telematics can be applied to improve road safety. The initial use has mainly been for

vehicle fleets, with one UK fleet (Andrew Page: http://www.andrewpage.com) reporting a 97% reduction in speeding and a 47% reduction in crashes (ETSC, 2016: Masternaut, 2016). That fleet also reported reduced maintenance costs and improved fuel economy. Some systems in the USA are promoted to parents as a way of monitoring teenage drivers.

Pay-How-You-Drive Insurance

Car insurance companies are continually trying to improve their assessment of customer risk so that premiums can better match the likelihood of an insurance claim. A promising new use of telematics is by car insurance companies that wish to give incentives for less risky driving, particularly by young drivers. In recent years several telematics trials have been conducted. Initially these looked at distance travelled and other simple parameters. More recently the availability of advanced telematics means that the manner in which a person drives can be recorded and analysed. One successful trial by the University of Sydney reported the following (Greaves and Fifer, 2011):

> "Pay-How-You-Drive (PHYD) products are being increasingly offered through the commercial insurance sector. While undoubted challenges remain, GPS technology opens up the possibility for developing greater equity in charging systems that reflect not just the kilometres driven but when, where and how they are driven...it has been demonstrated that it appears possible to significantly change aggregate behaviours (particularly speeding) of a segment of the motoring public through financial leverages based on incentivising positive changes in driving behaviour."

That project used an on-board recording system that included a digital map of Metropolitan Sydney speed limits and a GPS to determine vehicle position, speed and direction of travel. The system recorded incidents where the speed limit was exceeded. The driving characteristics of participants were recorded before they were told about the purpose of the trial in order to set a baseline of driver behaviour for the purposes of comparison. Participants were then offered moderate financial incentives to reduce the kilometres driven, reduce night-time driving and reduce episodes of exceeding the speed limit. As indicated above, the outcomes in reducing targeted areas of 'risky' behaviour were positive, particularly with regards to speeding.

Examples of PHYD insurance

In recent years several European car insurance companies have introduced PHYD insurance, and Australian car insurance companies have made similar initiatives. Some of these examples are described below. Note that inclusion here does not imply endorsement of these commercial products.

Ingenie

The UK insurance firm Ingenie (http://www.ingenie.com) offers PHYD insurance, mainly for young drivers. Ingenie won the 2013 Prince Michael Awards for Road Safety for Young Drivers (RoadSafe, 2013).

The steps described in the promotional material are:

1. An Ingenie telematics box is fitted out of sight in the car, collecting data on how the car is driven;
2. Data are transmitted from the box to secure servers via the EE network, allowing us to access your driving style;
3. We send you feedback on your driving which is available via the Ingenie app or online;
4. We give discounts to our best and most improved drivers, so drive well and you could pay less.

The website states: "We assess how you drive in 4 key areas: speed, braking, acceleration and cornering. On average our customers save over £500 when they insure with us." The Ingenie smartphone app gives the driver a driving score for the month and an indication of the premium discount ("Well done! You're on track for a £62 discount at your next price review."). The app also gives feedback on the assessed parameters ("Speed - Good. You're keeping to the speed limits - Ingenie rewards good driving. Keep it up!").

Insure-the-box

Insure-the-box (https://www.insurethebox.com/) is a UK insurance product that is similar to Ingenie. The website promotes an Accident Alert feature described as follows:

> "The in-tele-box fitted to your car can sense a strong impact on the car. When this happens, an alarm is activated in our Service Centre. If your car is stationary, we will try to call you to check you are OK and try to help you get going. If your car is moving we will assume you do not require urgent assistance. If we can't get in contact and your car is not moving we will assess all the circumstances relating to the incident. If appropriate, we will attempt to contact the emergency services."

QBE Insurance Box for Young Drivers

The Australian insurer QBE recently introduced Insurance Box PHYD insurance (https://www.qbe.com.au/insurance-box) described as follows:

> "When you take out a policy we'll send you an Insurance Box, a small device that plugs in under your dashboard. It transmits data such as speed, distance travelled and heavy braking. This helps us understand what kind of driver you are and your likelihood of having a collision. We then price your insurance based on the data."

According to QBE, they are the only Australian vehicle insurer currently offering PHYD insurance, although several have "pay-as-you-drive" polices that are based on vehicle odometer readings (distance travelled) but do not monitor the way in which the vehicle is driven.

NRMA Connected-Car

The motorist organisation NRMA in New South Wales recently introduced a telematics tracking system called Connected-Car (NRMA, 2017). It is targeted at commercial fleets and helps to monitor vehicle usage. It can produce driver score reports to encourage safer more efficient driving and has a smartphone app. It can also provide accident alerts.

At this stage the system does not appear to be used for the purpose of PHYD insurance but it is evident that the system has the same functionality as successful PHYD schemes.

Potential road safety benefits

There are numerous ways in which telematics can result in a reduction in road trauma. The following three areas are considered to have the highest potential benefits, when compared with other countermeasures.

Speeding

PHYD insurance is generally set to discourage speeding by several km/h over the speed limit. There is widespread misunderstanding of the proportion of road trauma associated with "low range" speeding (Paine, 2009; Doecke, 2011; ETSC, 2017).

In 2012, Prof. Holman from the School of Population Health, University of Western Australia, conducted research for the Road Safety Council of Western Australia (Holman, 2012). It was concluded that "52% of total killed and seriously injured (KSI) in [Perth] metropolitan 60km/h zones are attributable to illegal speeding". Furthermore, he analysed the contribution from each speeding range. In brief, it was estimated that about 15% of KSI would have been avoided if vehicles travelling between 1km/h and 10km/h over the speed limit had not been speeding. Four percent of preventable KSI were estimated to be in the range of 1km/h and 5 km/h over the speed limit. This is a range where most drivers feel they are driving safely and will not get fined for speeding. However, based on Holman's estimates, more than 800 KSI would be prevented each year across Australia if this group were not speeding.

Holman further found that the sensitivity to speeding is not as high in rural areas but low-range speeding (1km/h-10 km/h over the speed limit) still accounted for one third of speeding-related crashes, or 7% of all KSI on rural roads in Western Australia.

Traditional speed enforcement is not particularly effective for low-range speeding and PHYD insurance (or another telematics solution) may be particularly effective for discouraging low range speeding (Paine, 2013).

Forward collision avoidance

PHYD insurance may also discourage other risk taking such as following too closely and inattention. Crashes involving these behaviours are typically those for which forward collision avoidance technology can be expected to be effective. A 2012 study by the Centre for Automotive Safety Research (Anderson, 2012) concluded that "between 20 and 40 per cent of all fatal crashes and between 30 and 50 per cent of all injury crashes might be prevented with forward collision avoidance technology (FCAT) systems."

Crash alerts

As described above, the telematics used for PHYD insurance also has the capability to be used for crash alerts ("maydays"), where the monitoring organisation/insurer might call emergency services if a vehicle is involved in a high-severity crash in a rural area and there is no response from the driver to a mobile phone call. Prompt emergency services response to a road crash in unpopulated areas is known to reduce the risk of a fatality. For example, it has been estimated that an effective mayday system could reduce vehicle occupant fatalities by 5 to 10% in Finland (ITF, 2016).

Discussion

The effectiveness of telematics-based PHYD insurance on each of the above scenarios (speeding, forward collision avoidance and mayday assistance) is uncertain at this stage. The individual savings from the three scenarios are not cumulative and so the combined effect is unknown. As mentioned above, the Andrew Page fleet in the UK reported a 47% reduction in crashes after introducing telematics. In effect, this is similar to insurance company statements that PHYD insurance typically halves customer's premiums, since premiums are partly based on crash risk. It is therefore considered that 50% reduction in crashes is feasible through effective PHYD insurance.

PHYD telematics systems can be retrofitted to any vehicle and so can be introduced swiftly, without needing to wait for new vehicles (with desirable safety features) to replace older vehicles. The integration of smart phones with vehicle technology is expected to further enhance the introduction of PHYD insurance.

At this time, most Australian vehicle insurers appear to be reluctant to offer PHYD insurance despite the success of these systems demonstrated in the UK and USA. Since each Australian state usually has an over-seeing organisation for third-party injury insurance it might be worthwhile for these organisations to encourage PHYD insurance.

In the USA, according to the National Association of Insurance Commissioners, it is expected that 70% of vehicle insurers will use telematics by 2020 (NAIC 2017). Telematics-based insurance is already available in 42 US states, although not all safety-related risks such as speeding are currently covered.

It is anticipated that there may be a vocal group that opposes a "big brother" approach and denies that low-range speeding is a road safety problem. Under voluntary PHYD insurance schemes, people may miss out on the possible large insurance premium discounts that apply to those who are prepared to demonstrate that they are a low insurance

risk. Greaves (2011) points out that eventually insurers will need to raise the premiums for drivers who do not elect to have PHYD insurance because, in many cases, less risky drivers are effectively subsidising those drivers. In any case, it should be possible for fleets with PHYD telematics to negotiate with their insurers for premium discounts.

Influencing insurance products is not an area where governments have traditionally focussed attention but they could encourage uptake of the technology, including through government fleet operations. The support/encouragement of digital mapping of speed limits (already being undertaken for intelligent speed assistance - ISA) would also assist in the introduction of PHYD insurance in Australia.

Conclusion

Remarkable reductions in risky driver behaviour have been observed in trials of telematics-based incentives. PHYD insurance products have been successfully implemented in Europe and are evidently leading to substantial crash savings, reflected in insurance premiums being halved. Australia and other countries may gain road safety benefits by including PHYD insurance and associated telematics in their national road safety strategies.

Consumer demand for PHYD insurance should be encouraged - particularly now that at least one PHYD insurance product is available in Australia.

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Who Violates Traffic Rules?

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Key Findings:

- Traffic rule violations contribute to crashes including fatal crashes;
- Drivers aged less than 18 years were 'at-risk' to exceed the speed limit/safe speed for conditions, drive aggressively/ erratically, and disregard road signs;
- Drivers aged over 70 years were 'at-risk' to disregard traffic signals, and fail to yield the right-of-way;
- Drivers aged between 19 to 25 years were 'at-risk' of driving under the influence of alcohol and drugs;

Abstract

Traffic rule violations contribute to crashes including fatal crashes. This paper aims to investigate six different traffic rule violations and identify people who are 'at-risk' of committing violations and being involved in crashes. North Carolina crash data from 2010 to 2013 were analyzed. Drivers aged less than 18 years were 3.2 times more likely to exceed speed limits/safe speed for conditions, 2.4 times more likely to drive aggressively/erratically, and 2.7 times more likely to disregard the road and traffic signs compared to drivers aged between 26 to 40 years. Drivers aged over 70 years were 4.3 times more likely to fail to yield the right-of-way compared to drivers aged between 26 to 40 years. Drivers aged between 19 to 25 years were 1.4 times more likely to drive under the influence of alcohol or drugs and be involved in crashes. The results suggest that a diverse set of countermeasures may be needed to target drivers by age in order to reduce the number of traffic rule violations and eventually traffic fatalities.

Keywords

Traffic Violation, Crashes, Driver Age, Exceed Speed Limit, Driving Under the Influence

Introduction

Transportation officials set forward traffic rules to ensure smooth and safe travel for the public on roads. However, violation of those traffic rules is a major contributor to fatalities and injuries (Penmetsa, 2017). Motor vehicle crashes resulted in 40,200 fatalities during 2016 in the United States (National Highway Traffic Safety

Administration, 2017). According to NHTSA, drivers account for 94% of the traffic fatalities. Traffic violations such as driving under the influence of alcohol and speeding alone contributed to approximately 60% of the total fatalities in 2013 (NHTSA, 2014; 2015).

Traffic rule violations can be intentional or unintentional: in both cases, they are a threat to society. They not only put the traffic rule violators at risk, but also other road users (Penmetsa et al., 2017). According to Zhang et al. (2013) and Factor (2014), if drivers comply with the traffic rules, the number of fatalities may be significantly reduced. The objective of this study was to identify people who are 'at-risk' of committing traffic rule violations and eventually being involved in crashes.

Literature review

Older drivers are more likely to violate traffic rules at intersections compared to other drivers (Staplin et al., 1998; Braitman et al., 2007). These two studies found that older drivers accept unsafe gaps, perform unsafe lane changes, fail to detect the presence of other vehicle in the intersection, and, often fail to comply with stop signs.

Drivers younger than 18 years and older than 65 are more likely to be involved in crashes that occurred due to stop sign violations (Retting et al., 2003). Typical red light runners are male (Retting, 1999) and are aged between 18 to 25 years (Porter, 1999). Drivers aged 16 to 17 years are more likely to drive aggressively than those aged 18 to 20 years, who, in turn, are more likely to drive aggressively than those aged above 20 years (Paleti et al., 2010).

Penmetsa and Pulugurtha (2017a) investigated more than 20 traffic rule violations and risks associated with such harmful driving behaviors. Exceeding the speed limit was identified the riskiest traffic rule violation followed by driving under the influence of alcohol. Further, Penmetsa and Pulgurtha (2017b) ranked traffic rule violations based on several criteria such as frequency, crash severity, and cost. The top six traffic rule violations ranked in order were

(1) going the wrong way, (2) driving under the influence of alcohol, (3) operating vehicle erratically or aggressively, (4) failure to yield the right-of-way, (5) exceeding authorized speed limit, and (6) disregarding traffic signal. These six traffic rule violations from Penmetsa and Pulugurtha (2017b) were considered for the analysis in this study except going the wrong way. Going the wrong way is more of an unintentional error by drivers, which can be prevented by improved ramp designs, signage, striping, etc. (Moler, 2002). Hence, instead of analyzing wrong way driving crashes, disregarding road signs (the next ranked traffic rule violation from Penmetsa and Pulugurtha (2017b)) was considered for analysis.

Methodology

Crash data were obtained from the state of North Carolina in USA from 2010 to 2013. A total of 855,900 crashes occurred during those four years. In order to identify people who are likely to have committed a traffic rule violation at the time of the crash, those with a traffic violation record versus those without were compared. Six different data sets were prepared for six traffic rule violations of interest. For example, to examine 'disregarding road signs' traffic violation, a binary dependent variable was created ('1' if a driver involved in the crash disregarded road signs, '0' if a driver involved in the crash did not commit any traffic rule violation). Drivers' age was the independent variable: ≤18, 19-25, 26-40, 41-55, 56-70, >70 years.

Logistic regression was performed using Statistical Analysis Software (SAS Institute Inc., 2012). The driver's age group between 26-40 years was used as a reference for driver's age. The odds ratio was used to quantify the effect and is defined as the ratio of an event happening to an event not happening.

Results

Descriptive analysis results are presented in Table 1. During the 4-year study period, North Carolina drivers failed to yield the right-of-way over 74,000 times. Of the 74,046 drivers who failed to yield the right-of-way, 673 were killed in crashes. 'Exceeding speed limit or safe speed limit for conditions' had the highest number of driver deaths compared to any other traffic rule violation. 'Disregarding road signs' had the lowest frequency, but were related to more driver fatalities than 'disregarding traffic signals'.

Table 2 summarizes the computed odds ratios of committing the respective traffic rule violation at the time of the crash.

Drivers of age less than 18 were approximately three times more likely and drivers aged between 19 to 25 years were twice as likely to exceed the speed limits than drivers aged 26-40 years. Drivers aged 70 years were less likely to exceed speed limit compared to drivers in the reference age group.

Drivers of age less than 18 years were 3.7 times more likely and drivers aged 70 years or more were over four times likely to fail in yielding the right-of-way compared to drivers aged 26-40 years. Drivers between 56 and 70 were 1.4 times more likely to fail to yield the right-of-way.

In North Carolina, the legal drinking age limit is 21 years. Even then, a substantial number of drivers aged under 21 years were involved in crashes whilst driving under the influence of alcohol. Drivers aged between 19 to 25 years were 1.4 times more likely to have been under the influence than drivers aged 26-40 years

Drivers aged less than 18 years were 2.4 times more likely to drive aggressively, erratically, or recklessly compared to drivers aged 26-40 years. Drivers aged between 19 to 25 years were twice as likely to drive aggressively.

Road signs for this study include stop sign, yield sign and other road signs. Drivers less than 18 years were 2.7 times more likely and drivers aged over 70 years were 2.5 times more likely to disregard the road and traffic signs than drivers aged between 26 to 40 years.

Table 1. Frequency of traffic rule violations

Traffic rule violation	Frequency	Frequency of Drivers' Deaths
Exceeding Speed Limit/Safe Speed for Conditions	47,970	1,041
Failing to Yield the Right-of-Way	74,046	673
Driving Under the Influence of Alcohol or Drug	15,180	880
Driving Aggressively/ Erratically/Recklessly	16,419	760
Disregarding Road Signs	7,715	603
Disregarding Traffic Signals	13,810	548

Table 2. Odds ratios of committing different traffic rule violations

Driver Age (years)	Exceeding Speed Limit / Safe Speed for Conditions	Failing to Yield the Right-of-Way	Driving Under the Influence of Alcohol or Drug	Driving Aggressively/ Erratically/ Recklessly	Disregarding Road Signs	Disregarding Traffic Signals
<18	3.21	3.72	0.60	2.42	2.75	2.06
19-25	2.01	1.80	1.42	1.99	1.77	1.64
26-40(R)	1.00	1.00	1.00	1.00	1.00	1.00
41-55	0.61	0.91	0.70	0.58	0.80	0.87
56-70	0.45	1.42	0.41	0.46	0.95*	1.18
>70	0.43	4.35	0.16	0.68	2.51	3.07

R reference category

* variable not significant at a 95 % confidence interval

Discussion and Conclusions

This paper identified people who are 'at-risk' of committing violations at the time of the crash in terms of driver age. A total of six traffic rule violations were investigated in this study. In North Carolina, failing to yield the right-of-way was the most frequently violated traffic rule followed by exceeding the speed limit/safe speed for conditions. Exceeding the speed limit/safe speed for conditions had the highest number of driver deaths compared to any other traffic rule violation.

Overall, drivers less than 18 years were 'at-risk' of exceeding the speed limit/safe speed for conditions, driving aggressively/erratically, and disregarding road signs. Drivers over 70 years were 'at-risk' of disregarding traffic signals, and failing to yield the right-of-way. Drivers between 19 to 25 years old were 'at-risk' of driving under the influence of alcohol and drugs. The results from this study suggest that a diverse set of countermeasures may be needed to target drivers by age in order to reduce the number of traffic rule violations and eventually traffic fatalities.

Drivers with high risk perceptions are less likely to take risks such as driving under the influence of alcohol, running red lights, etc. Young drivers perceive traffic rule violations less risky compared to older drivers (Penmetsa et al., 2017) and hence they are willingly likely to violate traffic rules. Even though older drivers have high risk perceptions, they still are 'at-risk' of committing violations and being involved in crashes. Past research suggests that older drivers' involvement in crashes is more due to cognitive and visual impairment (Owsley et al., 1991; Owsley et al., 1998; Ross et al., 2009).

While engineering treatments are vital to improve safety on roads, educating drivers about potential risk of violating a traffic rule is equally important. Studies such as Elder et al. (2004), Tay (2004), Lewis et al. (2007) have shown the effectiveness of public campaigns on improving road safety. The findings from this research could help target such education efforts by age and traffic violation.

More effective enforcement and penalty system may also help drivers comply with traffic rules. The North Carolina Department of Motor Vehicles (DMV) awards 3 penalty points if drivers are convicted of driving above the speed limit and revokes the license if convicted of driving 15 mph above the speed limit. Even though the number of crashes and fatalities occurred due to exceeding speed limit is very high, the number of penalty points applied is less compared to other less serious traffic violations such as passing on hill/curve. Revision of the penalty fine amount and points for traffic violations based on risks of fatal crashes may be beneficial to improve road safety.

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Calling for submissions

to the *Journal of the Australasian College of Road Safety (JACRS)*

August 2018 Issue: We are soliciting contributions for the August 2018 Issue on all topics of road safety. Sample topics may include, but are not limited to: evaluation of Safe System interventions; system designs protecting vulnerable road users; research related to child road safety and older driver safety; in-depth analyses of the rising or plateauing road deaths in New Zealand and Australian jurisdictions; policy and practice on sustainable transport and road traffic exposure reduction; research related to autonomous vehicles; case studies of road safety activities in low and middle income countries; commentary on road safety communications and advocacy leading to government actions.

SUBMISSION DEADLINE:

Peer-review papers: ***Wednesday, 24th May 2018***

Contributed (non peer-review) articles: ***Wednesday, 14th June 2018***

For more details on article types, the scope and requirements see the **Instructions to Authors** available from the ACRS website: http://acrs.org.au/contact-us/em-journal-conference-contacts/ (scroll down). Please submit your manuscript online via the Editorial Manager: http://www.editorialmanager.com/jacrs/default.aspx. Authors wishing to contribute papers and discuss their ideas with the Managing Editor in advance of submission or to ask any questions, please contact Dr Chika Sakashita**:** journaleditor@acrs.org.au

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Hard copies of the *JACRS* are also available at the National Library of Australia.

The *JACRS* citations are being indexed in the **Emerging Sources Citation Index (ESCI)** and citation activity is visible in **Web of Science**. We thank you for your continued support and contribution towards JACRS attaining an Impact Factor.

"Together we can improve road safety"

Become a member of the College today!

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

What membership benefits do we provide?

- **Communication** – weekly e-newsletters, quarterly peer-reviewed journal, social platforms (LinkedIn and Facebook), media releases... **We keep you up to date!**
- **Professionalism** – Awards, Code of Professional Conduct…. **We reward innovations to save lives and injuries!**
- **Accreditation** – Register of Road Safety Professionals…. **We support our experts!**
- **Networking** – National conference, Chapter events, social platforms…. **We keep you connected!**
- **Advocacy** – International, Australasia0n, National and Chapter-based advocacy…. **We talk to those in leadership positions on your behalf!**

Who can be members?

In a word: Everyone!

Individuals contribute a variety of views and perspectives.

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

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

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

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

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

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

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

- **Membership**

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

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

Showcase your support to combat road trauma and be associated with a prestigious organisation endorsed by the Governor-General of Australia.

- **Attending events**

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

- **Registering as a Road Safety Professional**

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

To become a member, contact the College:

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

Email – Finance and Administration:
faa@acrs.org.au

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 x $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**

SMART CUSHION
Speed Dependent Crash Attenuators

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