



# Journal of the Australasian College of Road Safety

Formerly RoadWise—Australia's First Road Safety Journal



## In this issue

### Contributed articles

- A note on the central stories of fatal and other cyclist accidents in Adelaide
- Piloting a Safe Cycle education program
- Encouraging safer cycling through the NSW BikePlan
- Cycling safety in the Australian Capital Territory
- Cycling safety in Victoria
- The Australian Bicycle Council and the *National Cycling Strategy*
- The Amy Gillett Foundation 'A metre matters' campaign and other initiatives
- The politics of cycling and cycling advocacy

### Peer-reviewed papers

- Crash prediction models and the factors that influence cycle safety
- Cycling injuries in Australia: Road safety's blind spot?
- Child cyclist traffic casualties: The situation in South Australia
- The effects of bicycle helmet legislation on cycling-related injury **RETRACTED See: V.21/4, V.22/1**
- Cyclist visibility at night
- The role of traffic violations in police-reported bicycle crashes in Queensland
- Painting a designated space: Cyclist and driver compliance at cycling infrastructure at intersections

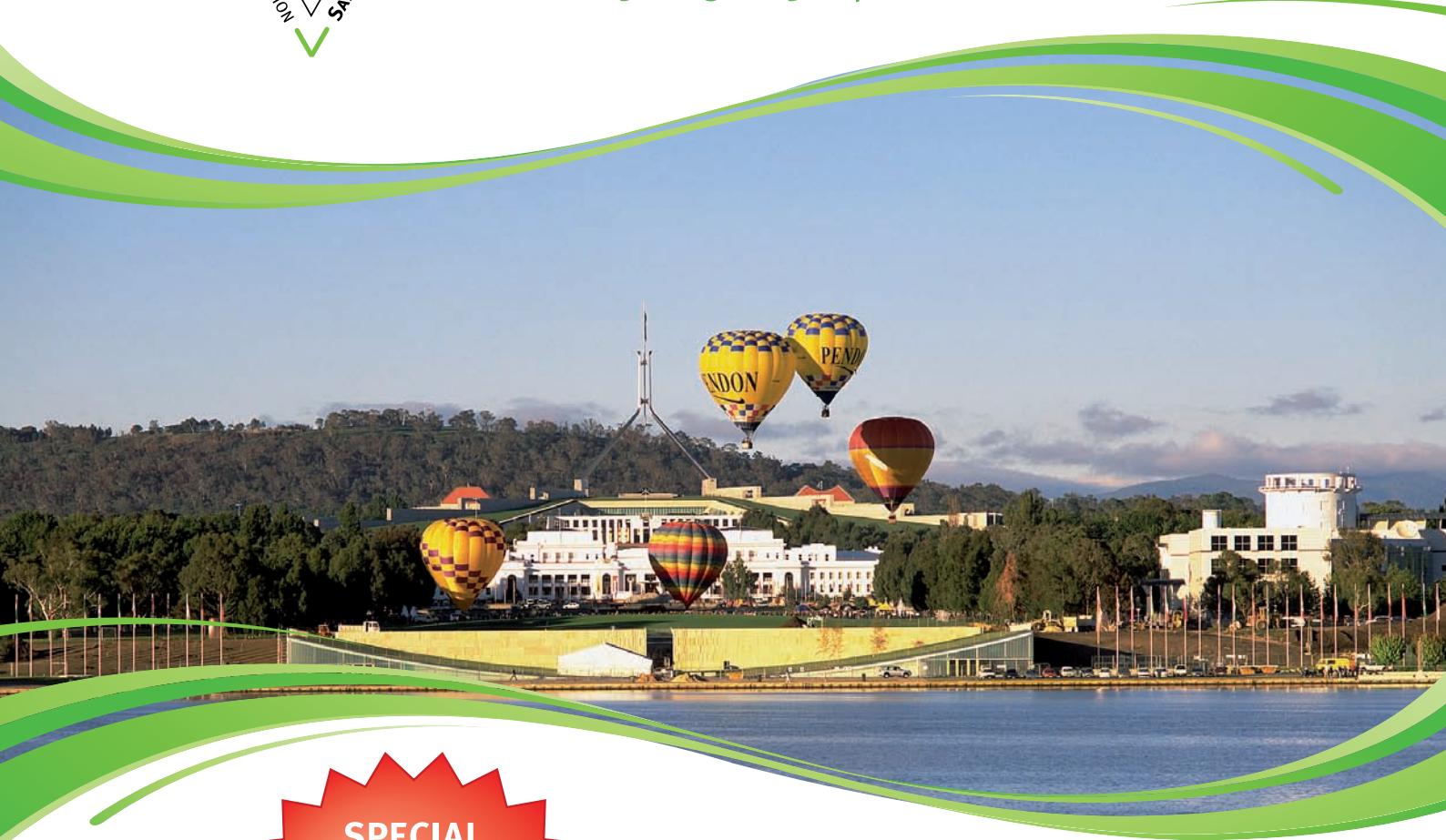


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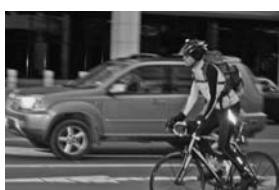
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### Cover photo

As the number of cyclists increases, more needs to be done to ensure their safety.

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## From the President



Dear College Members,

We are pleased to present this special August journal, which is dedicated to bicycling safety. Our sincere thanks go to Dr Julie Hatfield, who has served as guest editor, for what is a bumper edition.

In the last journal I asked for your ideas on what the College should suggest as campaign issues for the coming federal election. We prepared a comprehensive document that sets out the key features of a national road safety policy, together with some specific examples for the political parties to consider.

Our Executive Officer Linda Cook and I presented the document to the House of Representatives Standing Committee on Infrastructure, Transport, Regional Development and Local Government in June and copied the report to other key politicians. The report is on the ACRS website at (<http://www.acrs.org.au>) in the 'What's new' section.

Can I urge you to talk to your local candidates about road safety, so that hopefully they can make commitments to all Australians to bring about change and reduce unnecessary road trauma. Every College member, I am sure, has a particular issue that they can speak confidently about to a candidate, either before or after the election. (It may, of course, have been held by the time you read this.) Every candidate will be listening to voters on many topics from health to economics; if we do not raise road safety, then our issues will be drowned out by others.

You will also notice in the media section of our website a very well argued article entitled 'High-speed driving should stay on the track' by our colleagues Lori Mooren and Raphael Grzebieta. Well researched responses to what are often popular 'myths' in road safety issues are vital if we are to ensure the professional views are heard and understood.

Last month one of Australia's well known motoring writers raised what he saw as a dilemma in speaking to a taxi driver regarding the driver's use of a mobile phone while driving.

I guess we all face that dilemma at times, and it is interesting that the first social issue we consider is whether to act and criticise the taxi driver and face some potential abuse. In the motoring writer's case, he elected to say nothing as he was late for an appointment and was relieved when he arrived safely.

However, the real issue that so many of us overlook in that situation is all the other road users. Had there been an incident resulting in trauma to a pedestrian, cyclist, truck or car occupant, or worse, bus or tram occupants, then he would have been not only late but potentially accountable for that incident.

This is a difficult issue for many of us. Encouraging everyone – road users, car manufacturers and road builders – to share the responsibility for a safe road environment and to do something themselves is a tough, but vital task. I would welcome your views.

*Lauchlan McIntosh AM, FACRS  
President*

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## Guest editorial



*Dr Julie Hatfield is the guest editor for this special journal issue on bicycling safety. She has been conducting behavioural research in road safety for over 10 years, with a focus on vulnerable road users, young drivers and driver distraction.*

*Dr Hatfield is currently a Senior Research Fellow at the NSW Injury Risk Management Research Centre (IRMRC), where she conducts high-quality, leading-edge research in road safety. One of her current studies of a large cohort of NSW cyclists aims to collect exposure, crash and injury data for different types of cycling infrastructure, in order to compare crash and injury rates and to investigate in detail factors that contribute to crashes.*

*Dr Hatfield has recently been invited as one of two Australian representatives on the Joint OECD/International Transport*

*Forum (ITF) Transport Research Committee Working Group on Bicycle Safety. She is a member of the Executive Committee of the Australasian College of Road Safety and the NSW Road Safety Taskforce.*

This special issue of the journal excites me because there is so much useful research, policy and advocacy relating to cycling safety currently under way in our part of the world. It's equally exciting that these activities address a need presented by increasing levels of cycling participation.

As devoted as Australians are to their cars, they are also fervent bicycle users. According to the Australian Bicycle Council, 1.15 million bicycles – almost three-quarters of them adult bicycles – were imported into Australia last year, exceeding motor vehicle sales by 123%. Indeed, bicycle sales have substantially exceeded motor vehicle sales in every year since 2001.

Cycling has many benefits to the individual and to the community. It is a healthy activity – one that reduces all-cause mortality and cardiovascular risk and is an important tool in the

fight against the obesity epidemic. It is environmentally friendly as well: as a major alternative means of commuting, cycling can reduce carbon dioxide emissions and other pollutants, as well as reducing traffic congestion. Cycling also has economic benefits and enhances social cohesion and urban liveability.

It is gratifying to see the benefits of cycling recognised by strategies to encourage cycling that exist at all levels of government. Moreover, many of these strategies explicitly recognise that if cycling is to be encouraged, it is imperative to maximise cycling safety – not only as a duty of care, but also because people are more likely to cycle if they perceive it to be safe. Interestingly, some evidence suggests that as cycling rates increase, cycling becomes safer (see Turner et al. in this issue) – perhaps because of associated improvements in cycling infrastructure and greater awareness and acceptance of cycling.

As cyclist numbers increase, it is critical to provide a safe cycling environment in order to avoid increases in numbers of cycling casualties (see Garrard et al. in this issue). To make cycling safer, we need to know more about the relative merits of different types of infrastructure in terms of user preference and safety (see Johnson et al. in this issue). On existing evidence, the choice between separated bicycle paths, paths that are shared with pedestrians and on-road cycle lanes is not straightforward, and previous research has often been limited by the lack of information about where and how much people cycle.

We also need better speed management: developing ‘cycling corridors’ that are speed limited to 30km/h, for example, is gaining sway internationally. Such corridors could allow cyclists to travel more safely and make more direct journeys, while also offering pleasant urban environments. Higher-speed alternatives would remain for motorised traffic.

A shift in attitudes of road users is also important. The notion that ‘roads are for cars’ cannot be maintained in the face of climate change, urban crowding and congestion, and with calls for more liveable cities. The ‘war’ between motorists and cyclists – often hyped up by a sensation-hungry media – must give way to an attitude of shared respect.

Finally, we need a whole-of-government approach to improve cycling safety. Fragmented responsibilities produce fragmented cycling infrastructure that does not allow for connected and safe cycling trips.

At present, the signs are good for safer cycling. More and more, policy-makers and advocates recognise the need for a unified approach. As the papers offered in this issue of the journal show, the required evidence base is growing steadily. In short, we have a growing momentum – based on knowledge and the will to work together – to get more people cycling safely.

*Dr Julie Hatfield*

## RRSP profile – Senior Research Fellow Lori Mooren



*Following the introduction of this feature in the May 2009 journal, we are continuing to profile in each issue an ACRS member who is on the ACRS Register of Road Safety Professionals. To be on the Register, applicants must satisfy stringent criteria. They must have relevant academic qualifications, have worked for at least five years at a senior level in their particular field of road safety, and be acknowledged as an expert by their peers. For details, visit [www.acrs.org.au/professionalregister](http://www.acrs.org.au/professionalregister).*

Lori Mooren is a Senior Research Fellow, Injury Risk Management Research Centre, at the University of NSW. She is accredited as a Registered Road Safety Professional by the Australasian College of Road Safety, signifying recognition by her peers of her outstanding achievements in road safety.

Lori holds a Master’s degree in Social Science from Dalhousie University, Canada, and a Bachelor’s degree in Sociology and Government from Eastern Washington University, USA. She has been working in road safety for more than 20 years. She worked as a senior road safety policy and program manager for the RTA, NSW, from 1989 until 2000, ultimately filling the role of General Manager, Road Safety. In 1998 she presided over the NSW government road safety program that achieved the lowest road fatality record since 1949. The road safety strategy she developed for the years 2000-2010 achieved road

levels that rival the world’s best performing countries.

Lori was the Project Manager for the production of a Global Good Practice Manual on Speed Management, co-sponsored by the World Health Organisation, World Bank, FIA Foundation and Global Road Safety Partnership.

She is the chair of the Work-related Road Safety Project Group of the United Nations Road Safety Collaboration (UNRSC), member of the Road Traffic Injury Researchers Network (RTIRN), member of the (US) TRB Bus and Truck Safety Committee, co-chair of the Subcommittee on Alternative Compliance and secretary of the Sydney Chapter of the Australasian College of Road Safety (ACRS). Since March 2004, Lori has also been the Fleet Safety ‘topic expert’ and has co-led a series of Fleet Safety Benchmarking Workshops with participants from over 100 companies.

Since joining the Injury Risk Management Research Centre, she has established a research program that aims to develop and test safety management systems and interventions to improve work-related road safety, particularly in heavy vehicle transport operations.

Her international road safety work has involved missions, projects and conference presentations in Bangladesh, Cambodia, Canada, France, Hungary, Honduras, India, Malaysia, Nepal, the Netherlands, Nigeria, Norway, Oman, Senegal, South Africa, Sri Lanka, Sweden, Switzerland, Thailand, UK, USA and Vietnam.

*We asked Lori the following questions:*

**How long have you been a member of ACRS?**

I joined so long ago that I cannot remember the date. However, I have been very actively involved in the College since around May 2000, when I approached Sydney-based road safety colleagues to establish the Sydney Chapter. This was achieved through meetings with a number of ACRS members, and we elected Professor Robyn Norton as the first chair of the Chapter. I was elected that year to the National Executive Committee and served in that role until two years ago. In addition, I have been actively involved in the Sydney Chapter Executive Committee and have assisted the organisation of many College seminars in Sydney.

**What do you value most about your membership?**

The great thing about being a member of ACRS is that it keeps me in touch with the range of road safety professionals and interdisciplinary issues and developments in this field. I take delight in reflecting on how the College has grown, developed and blossomed into a strong professional association, of which I am proud to be a member.

**What is your particular expertise in road safety?**

I began my road safety life in late 1989, transitioning from a public health and health promotion management role with a particular interest in injury prevention, to a road safety development role with the RTA. This entailed developing, implementing and evaluating strategic public education and social marketing campaigns coordinated with police

enforcement operations and other community and stakeholder activities. Later, I was appointed as the General Manager, Road Safety, with senior policy and program responsibilities for all aspects of road safety – road, vehicle and equipment, school and public education, legislation/regulation, and overall strategic management and stakeholder coordination.

Since leaving the RTA in early 2000, I have been involved as a consultant in the arenas of work-related road safety and international road safety. Currently I am particularly seeking to contribute to the emerging field of work-related road safety both nationally and internationally. My special research focus at the university is the development of safety management systems suitable and effective for heavy vehicle transport operations

**What is a typical working day for you?**

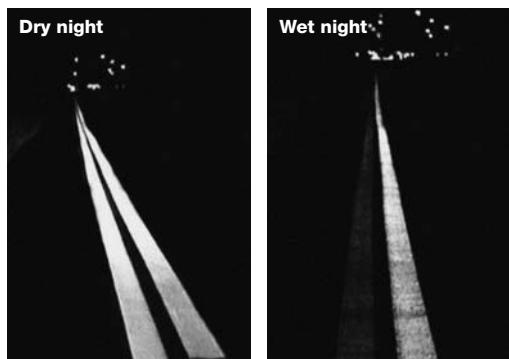
At the moment, my typical working day involves researching the literature on safety management systems and safety culture, and working towards a refinement of methods for a major five-year research project funded through an Australian Research Council Linkage program, together with contributing partners Roads and Traffic Authority, NSW, Motor Accidents Authority, Transport Certification Australia and Zurich Insurance.

I also meet from time to time with industry stakeholders for a greater understanding of current issues and challenges. My days are also sprinkled with attention to my role in the United Nations Road Safety Collaboration, and current efforts to develop a Decade of Action plan to be adopted by the UN General Assembly for implementation from 2011-2020.

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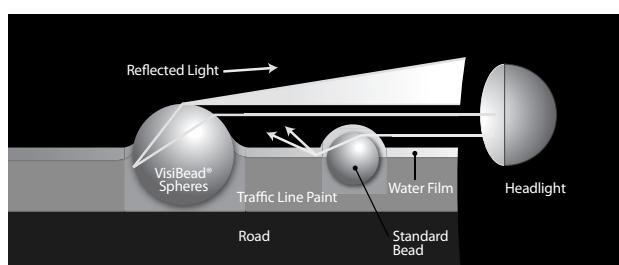
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[rta.nsw.gov.au](http://rta.nsw.gov.au)



# Quarterly News

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## ACRS College Fellowship



The ACRS is pleased to announce that the award of 2009 College Fellowship will be made to Professor Barry Watson, Director of the Centre for Accident Research and Road Safety at Queensland University of Technology in Brisbane. The presentation will be held at the Road Safety Research, Policing and Education Conference in Canberra on

2 September 2010. The many College members who will be attending the conference are asked to join in this occasion and

acknowledge Barry's contribution to both the College and road safety in general.

Barry will join a list of Fellows elected annually since 1992. The full list of those honoured by the award of a fellowship is available at <http://www.acrs.org.au/collegefellowships/acrsfellowslist.html>.

ACRS members will be invited to nominate a current member of the College for the 2010 Fellowship. Guidelines and a nomination form for fellowships will be published via the web and members will be notified.

## Chapters

### Australian Capital Territory and Region

Canberra motorists will be subject to roadside drug tests after the ACT Legislative Assembly recently passed new laws. The Bill was put forward by the Opposition with the support of the Greens. Under the new laws Canberra motorists will face random tests for ecstasy, cannabis and methamphetamine. The ACT Government does not support the new laws, citing human rights concerns, limited coverage and potential legal challenges. It is not clear when the laws will come into effect.

The Chapter is considering conducting further seminars as part of its ongoing seminar program. The seminars will focus on road safety communication and child safety. The road safety communication seminar will have Dr Stephen Jiggins as the main speaker and will focus on the issues identified in his 2008 Churchill Fellowship, which examined issues associated with news media reporting of road crashes. In a somewhat similar vein, the second seminar will showcase findings from another recent Churchill Fellowship involving Mr Eric Chalmers, Director of Kidsafe ACT.

Both seminars will include a range of other supporting speakers. Current plans are to conduct the one-day seminars towards the end of 2010, as the Chapter is anxious to avoid any clash with the 2010 Australasian Road Safety Research, Policing and Education Conference, which is taking place in Canberra in September.

*Steve Jiggins, ACT and Region Chapter President and Representative on the ACRS Executive Committee*

### New South Wales

The College ran a successful seminar prior to the national annual general meeting. The seminar, entitled 'Decade of Action for Road Safety – A United Nations resolution', was held at the Sydney University Village in Newtown. Dr Soames Job from the RTA spoke as a member of the United Nations Road Safety Committee (UNRSC) about the 'UN road safety resolution calling for a Decade of Action' in New York in March 2010. Lori Mooren from UNSW, also a member of the UNRSC, spoke about the 'Decade of Action – The plan in development and the role of the UN Road Safety Collaboration'.

Continuing with the UN's call for a Decade of Action for Road Safety, the College ran a successful and well attended half-day workshop for road safety professionals on 25 July at the RTA's Miller Street conference theatre. Speakers and participants focused this time on 'The Decade of Action and Australia's Road Safety Strategy'. Speakers were Wayne Gardner, motorcycling champion and member of the National Road Safety Council; Dr Soames Job, Director of the RTA's Centre for Road Safety, who spoke on the 'Australian Road Safety Strategy'; and Lori Mooren from the Injury Risk Management Research Centre (IRMRC) at UNSW, who spoke on 'Decade of Action – Framework for the plan'. Breakout sessions were held on several topics: 'Safer speeds', 'Safer road infrastructure', 'Safer vehicles', 'Safer people' and 'Road safety management and post-crash care'. A summary of the workshop will be published in the journal in November.

A cycling seminar, 'Toward best-practice cycling infrastructure', is planned for September at the Parliament of NSW Theatrette. The seminar is being chaired by Dr Julie Hatfield from the IRMRC, UNSW. State-of-the art research relating to which types of infrastructure offer the safest cycling environment will be presented, and the possibility of recommendations for best-

practice cycling infrastructure will be discussed. Potential speakers for the event are Dr Shane Turner, Dr Jan Garrard, Associate Professor Stephen Greaves and Ms Marilyn Johnson. The primary audience targeted for this workshop is ACRS members and potential members who are researchers or practitioners with an interest in cycling safety.

Finally, it is worth noting that NSW has at last caught up with the rest of Australia and introduced mobile speed cameras on 19 July. There has been considerable debate by the media as expected, with the usual set of myths being promulgated by the speedsters.

As road safety professionals, we should note this date in our calendars. It will be interesting to see whether there is a downturn in the number of fatalities – which has remained consistently at around 80 or higher (for 2009 and so far for 2010) than NSW's best year (2008) of 374 fatalities – over the next two or so years as the enforcement starts to take effect. This would once and for all silence those who advocate that such enforcement has no effect and that speed is not related to the number of fatalities and serious injuries.

*Professor Raphael Grzebieta, NSW Chapter Chairman and Representative on the ACRS Executive Committee*

## Queensland

The Queensland Chapter held its quarterly seminar and Chapter meeting on 1 June 2010. The seminar was presented by Mr Bruce Ollason, General Manager, Road Safety and System Management Department of Transport & Main Roads – Queensland.

In addition, the election of office bearers for 2010 was conducted. Dr Kerry Armstrong stood down from the Chair while Professor Jeremy Davey carried out the election process for committee members for 2010. The following people were nominated and elected unanimously:

Chair	Dr Kerry Armstrong
Deputy chair	Mr Lyle Schefe
Secretary	Professor Barry Watson
Treasurer	Ms Veronica Baldwin
Committee	Ms Pam Palmer Mr Graham Smith Ms Kelly Sultana Acting Superintendent Col Campbell Mr Peter Coughlan Ms Kerrieanne Watt

Professor Davey congratulated the 2010 committee members and handed the meeting to the chair. Kerry Armstrong thanked members for their support. The next Queensland Chapter meeting and seminar is scheduled for Tuesday, 7 September 2010.

*Dr Kerry Armstrong, Queensland Chapter Chair and Representative on the ACRS Executive Committee*

## South Australia

Professor Fred Wegman, the Managing Director of the SWOV Institute for Road Safety Research in the Netherlands, has recently been in Adelaide as a Thinker in Residence to address the challenge: How can we make our roads safer? (See <http://www.thinkers.sa.gov.au/thinkers/wegman/who.aspx>). He will be returning in November to finalise his report to the Premier. The next Chapter seminar will be on 'Road safety in urban planning'.

*Jeremy Woolley, South Australian Chapter Representative on the ACRS Executive Committee (based on the 8 July 2010 minutes of the Executive Committee)*

## Victoria

The Chapter conducted a very successful seminar on motorcycle safety with an attendance of over 40 and important contributions from ACRS executive members Raph Grzebieta and Liz de Rome. The next seminar, which is to be on the topic 'Road safety in 20 years', has had to be postponed in light of presenters being unavailable at the suggested time. A new date and venue are yet to be set.

The College has now started to plan for the conduct of the ACRS 2011 Conference. The dates have been set as 11-12 August 2011, with venue to be decided and sponsorship packages to be finalised for invitations to be dispatched from the national office. It is likely that a call for abstracts will take place in November.

*David Healy, ACRS Co-Vice President and Victorian Chapter Representative on the ACRS Executive Committee*

## New Zealand

The New Zealand Government released its *Safer Journeys* road safety strategy in March this year. Safer Journeys is a strategy to guide improvements in road safety over the period 2010 to 2020. The new strategy adopts, for the first time in New Zealand, a Safe System approach to road safety with a long-term vision of providing 'a safe road system increasingly free of death and serious injury'.

In June, the New Zealand Transport Minister welcomed the new KiwiRAP star ratings for New Zealand state highways, saying they provide important information for drivers, road controlling authorities and the government. The New Zealand Road Assessment Programme, KiwiRAP, is a road safety partnership between the Automobile Association and New Zealand government agencies that provides an assessment of the relative levels of safety built in to our state highways.

ACRS activity has been relatively quiet during recent years in New Zealand. Over the coming quarter Fabian Marsh, as new Chair of the New Zealand Chapter, will be looking for opportunities to grow the New Zealand membership. He will also be looking to increase awareness of the College by planning a potential seminar on motorcycle safety and by encouraging others to contribute to the *ACRS Journal*.

*Fabian Marsh, New Zealand Chapter Chair and Chapter Representative on the ACRS Executive Committee*

# Australian and New Zealand news

## Ride to Work Day

National Ride to Work Day will be held this year on 13 October. Ride to Work is a program that encourages workers to experience the economic, health and environmental benefits of riding. The program is free and assists those wanting to commute to work using an alternative mode of transport. It is now in its 4th year nationally, and 17th year internationally. Ride to Work Day 2009 was very successful, with 95,000 participants collectively pedalling over 700,000km.

Participants are encouraged to register their ride online at <http://www.bv.com.au/ride-to-work>. This assists organisers to understand bike commuter behaviour and to campaign more effectively at local, state and federal government levels for better riding facilities.

## Bicycling Achievement Awards

The 2009 Australian Bicycling Achievement Awards were presented in Canberra on 16 June 2010. The awards are organised by the Cycling Promotion Fund, with the National Heart Foundation of Australia as principal partner. The objectives of the awards are to:

- recognise innovation, commitment and contribution towards promoting and encouraging cycling
- lift awareness and the profile of innovative programs that are effective in increasing cycling
- share best practice examples to encourage innovation
- celebrate achievements and sustain momentum.

There are seven award categories, including local government, educational institutions, politicians and retailers. More information and the list of this year's recipients are at <http://www.cyclingawards.com.au/node/1>.

## Study of NSW cyclists

Researchers at the University of New South Wales, including Dr Ros Poulos, Dr Julie Hatfield, Professor Raphael Grzebieta, Associate Professor Andrew McIntosh and Associate Professor Chris Rissel, are undertaking a large cohort study of NSW cyclists. Entitled 'Safer cycling: A partnership project to better understand cycling patterns, hazards and incidents', the study will provide much needed data to inform policy and planning for safer cycling. Researchers hope to enrol 2000 cyclists to measure cycling crash, near miss and injury rates over a one-year period. These rates will be examined in the light of attitudinal and behavioural factors, exposure (distance and duration of travel), and infrastructure utilisation.

In addition to the data gained through questionnaires, a rich source of contextual understanding will be added to the

research through interviews with enrolled cyclists who experience crashes and through a series of detailed engineering safety audits on a sub-sample of crash locations. The research is being funded by an ARC Linkage Grant, with RTA, Bicycle New South Wales, Sydney South West Area Health Promotion Service and Willoughby City Council as research partners.

If you are a cyclist and interested in being part of the study, please contact Dr Ros Poulos [r.poulos@unsw.edu.au](mailto:r.poulos@unsw.edu.au). The project also offers exciting opportunities for suitably qualified persons wanting to undertake a higher degree by research (PhD or Masters by research). Interested persons should contact Dr Ros Poulos ([r.poulos@unsw.edu.au](mailto:r.poulos@unsw.edu.au)).

## Inquiry into vulnerable road users

Following on from its recent inquiry into Pedestrian Safety, the NSW Staysafe (Road Safety) Committee is conducting a parliamentary inquiry into vulnerable road users. The terms of reference for the committee are to inquire into and report on vulnerable road users, specifically motorcycle and bicycle safety, with particular reference to:

- a) patterns of motorcycle and bicycle usage in New South Wales
- b) short and long term trends in motorcycle and bicycle injuries and fatalities across a range of settings, including on-road and off-road uses
- c) underlying factors in motorcycle and bicycle injuries and fatalities
- d) current measures and future strategies to address motorcycle and bicycle safety, including education, training and assessment programs
- e) the integration of motorcyclists and bicyclists in the planning and management of the road system in NSW
- f) motorcycle and bicycle safety issues and strategies in other jurisdictions
- g) any other related matters.

The closing date for submissions was 6 August 2010. More information is at <http://www.parliament.nsw.gov.au/Prod/parlment/committee.nsf/0/BD0C30FA449977D9CA2577270021AA13>.

## Public bike hire rolls out

Melbourne Bike Share was launched in May this year. Bike sharing is increasing in popularity, with more than 90 programs comprising about 86,000 bicycles in some 135 cities on 4 continents – and many more in the planning stages.

Melbourne Bike Share is run by RACV in partnership with the Department of Transport as an alternative form of public transport in Melbourne's CBD. The 600 distinctive blue bikes (see Figure 1) and 50 bike stations are at convenient locations across Melbourne, providing a sustainable, healthy and community-based transport option. For more information on individual and corporate subscriptions see [www.melbournebikeshare.com.au](http://www.melbournebikeshare.com.au).



**Figure 1.** One of the 600 distinctive blue bikes that are part of the new Melbourne Bike Share program

CityCycle is a world class public bike hire scheme primarily designed for Brisbane residents and commuters making short trips within the inner city. It will be launched late in 2010. The scheme provides an affordable, clean and green alternative to travel by car, aimed at reducing traffic congestion and local parking pressures, as car trips are replaced by cycle trips.

CityCycle bike hire stations will be located at key inner city destinations linking to bus, train and ferry connections. Construction has commenced for stage one CityCycle stations in Brisbane City, Fortitude Valley, New Farm, Newstead, Kangaroo Point, South Brisbane and West End. For more information visit [www.brisbane.qld.gov.au](http://www.brisbane.qld.gov.au).

### Cycle training for new arrivals

In April, the City of Charles Sturt held a special school holiday cycle safety training course for 17 young people who had recently arrived in Australia. They came from countries across the world, including Afghanistan and Somalia, and some had never ridden a bicycle before. The course was delivered with the support of the South Australian Police (Port Adelaide), the Bicycle Institute of South Australia and CycleWorx, and was supported through the Department of Transport, Energy and Infrastructure's Local Government Partnership program.

The aim of the program was to improve the skills and confidence of these new arrivals when riding a bicycle. After successfully completing the course, all 17 participants were provided with a reconditioned bike and new accessories, including a helmet, lights and lock, to ensure they could continue to practice their cycling skills safely. (*Source:* [http://www.dtei.sa.gov.au/roadsafety/latest\\_news/e-newsletter\\_edition\\_8/#onyabike](http://www.dtei.sa.gov.au/roadsafety/latest_news/e-newsletter_edition_8/#onyabike))

### Island cycle transport corridor

Tasmanians and island visitors can look forward to a more connected network of cycle ways to help them keep fit, enjoy touring and live more sustainably. On 30 June the Tasmanian Government announced it was providing an extra \$2 million over four years to help develop cycle ways across the state. The new funding is on top of the \$2 million still available in 2010-11 under the Trails and Bikeways program.

Part of the funding package is a feasibility study for a Smithton to Hobart bike track. Such a proposal would link existing cycle tracks so that, for the first time, Tasmania would have a sustainable cycle transport corridor from end to end.

(*Source:* <http://www.media.tas.gov.au/release.php?id=29868>)

### New Zealand

The road safety research team at Beca Infrastructure Ltd (Dr Shane Turner, Tracy Allatt, Rohit Singh and Gary Nates) is currently undertaking a study that aims to quantify the safety impact of various traffic signal phasing configurations and levels of intersection congestion at low- and high-speed traffic signals in New Zealand and Australia. In addition to signal phasing and congestion, the study will examine factors such as intersection geometry and will assess the effects of these factors on safety of three different modes of travel – namely motorists, cyclists and pedestrians.

The research draws on data from intersections located in five New Zealand cities (Auckland, Wellington, Christchurch, Hamilton and Dunedin) and in Melbourne. The final outcome of this study will be a set of crash prediction models for individual modes of travel and time periods. The results will be particularly relevant for road safety engineers, who typically rely on anecdotal experience of the effects of various factors on safety, and will provide a much needed quantitative tool for assessing the safety impact of changes in phasing and geometry. The study will look at the trade-offs in safety of making safety improvements for one particular mode or crash type, which may reduce the safety of other modes and crash types.

For further information on this study, entitled *Crash Prediction Models for Signalised Intersections – Signal Phasing and Geometry*, contact Dr Shane Turner at [shane.turner@beca.com](mailto:shane.turner@beca.com).

Although there are many guidance documents available for the design of cycle facilities, there is a currently very little content on the effectiveness of different types of treatments, particularly at intersections. The research team at Beca, in conjunction with Tim Hughes of the New Zealand Transport Agency, is in the



final stages of another research study that builds upon research already undertaken in Australia and New Zealand and uses statistical methods to quantify the safety effects of different types of cycle facilities.

This study, which uses data from intersections located in Christchurch and Adelaide, aims to improve the understanding of the effectiveness of different intersection treatments for cyclists, so that better guidance can be provided on appropriate provisions for different types of intersections. Crash prediction models are being developed for various crash types at intersections, and these models will be able to predict the safety effects of various cycle treatments such as approach and departure cycle lanes, storage boxes and painting at intersections. For further information on this study, *Effectiveness and Selection of Intersection Treatments for Cyclists*, again contact Dr Shane Turner.

## Worldwide news

### Denmark

Road safety research was one of the themes at Velo-city Global 2010 (<http://www.velo-city2010.com>), the world's largest cycling conference, held from 22 to 25 June in Copenhagen. Topics included:

- Safety effects of bicycle facilities, traffic calming and signalisation in Copenhagen
- Improving road safety in Münster
- Surface of cycle paths and its influence on the health and safety of cyclists
- Is cycling a safe mode? Comparing apples with apples.

And concerned that 'the main effect of helmet laws has not been to improve cyclists' safety but to discourage cycling, undermining health and other benefits', the European Cyclists'

Federation (ECF) promoted their campaign against mandatory bicycle helmets with super-sized buttons labelled 'Ask me why I cycle without a helmet'.

*Report by Brenda Mattick, Bicycle NSW*

### France

The OECD International Transport Forum Working Group on Cycling Safety met for the first time on 10-11 July in Paris. The Working Group will prepare a report that summarises the international situation relating to:

- trends regarding bicycle use and safety, including an inventory of existing cycling infrastructure in OECD/ITF countries
- bicycle accident patterns by age group
- current policy measures, administrative frameworks and funding structures for bicycle safety
- measures to improve safety of bicyclists and their efficacy.

The report will also explore:

- the possibility of best practice benchmarking using international comparisons
- stated preference of different modal choices in response to hypothetical safety improvements
- the potential of each potential policy instrument, based on analysis of efficacy, modal choice, and barriers to implementation.

The report, to be available by August 2011, will target policy-makers, but will also aim to provide academics and other stakeholders with useful information related to cycling safety. The first draft of the report should be prepared in time for the second meeting of the Working Group, to be held in Paris in December 2010. If you are aware of data addressing the aims of the report at the national or state level, please contact Julie Hatfield ([j.hatfield@unsw.edu.au](mailto:j.hatfield@unsw.edu.au)).

## Diary 2010

**31 August - 3 September, Canberra.** Australasian Road Safety Research, Policing and Education Conference, to be held at the National Convention Centre.

[www.roadsafetyconference2010.com.au](http://www.roadsafetyconference2010.com.au)

**10 September, Parliament House, Sydney.** Toward Best-Practice Cycling Infrastructure, a seminar hosted by the ACRS Sydney Chapter. Speakers include Dr Shane Turner (Beca, NZ), Dr Jan Garrard (Deakin University), Associate Professor Stephen Greaves (University of Sydney) and Ms Marilyn Johnson (Monash University). To register your interest in attending, contact Dr Julie Hatfield ([j.hatfield@unsw.edu.au](mailto:j.hatfield@unsw.edu.au)) and provide your name, organisation and contact details.

**13-15 October, Melbourne.** Australian Road Research Board (ARRB) Conference.

[www.conferenceworks.net.au/arrb/arrb/index](http://www.conferenceworks.net.au/arrb/arrb/index)

**13-15 October, Bunbury, Western Australia.** National Local Roads and Transport Congress, Building the Case for Transport Investment.

<http://www.alga.asn.au/policy/transport/congress>

# Contributed Articles

*Future issues of the journal will have themes as follows:*

*November 2010 – Occupational health and safety related to road safety*

*February 2011 – Road safety in the Asian region*

*May 2011 – Heavy vehicle safety (a special issue with guest editor Lori Mooren)*

*Members are invited to contribute articles related to these themes or on road safety more generally. Contact the Managing Editor ([journaleditor@acrs.org.au](mailto:journaleditor@acrs.org.au)) with respect to deadlines for receipt of articles.*

## A note on the central stories of fatal and other cyclist accidents in Adelaide

by TP Hutchinson and VL Lindsay, Centre for Automotive Safety Research, University of Adelaide, South Australia 5005

### Abstract

Cases in a routine (police) database and in an at-scene in-depth database were used to try to identify a central story for cyclist accidents. Four types of event accounted for 28 of the 37 fatal cases. These four types were same direction, motor vehicle into rear of cycle; same direction, side swipe; cyclist turned or swerved unexpectedly into path of motor vehicle; and cyclist emerged unexpectedly into path of vehicle from an intersection or footway.

### Introduction

The present note summarises our findings from a recent report on cyclist (and pedestrian) crashes in Adelaide investigated in the period 2002 to 2005 [1]. In part of that report we aimed to identify a central story for 11 cyclist crashes from at-scene in-depth investigations conducted by the Centre for Automotive Safety Research (CASR), and a further 37 fatal cyclist crashes from the police database of routinely reported crashes (known as TARS) for 1994 to 2006.

Information about the databases is provided in our full report [1]. There are reasons why we would expect the in-depth and TARS-fatal databases to differ from each other. First, the at-scene in-depth investigations were largely of crashes occurring on Monday to Friday in daytime, and so crashes in darkness and alcohol-related crashes were very much underrepresented. Second, the descriptions of crashes in TARS, even of fatal ones, were very brief, and it is possible that if more details were known, many different categories would become evident. Thus, neither database presents a complete picture.

As introduction to the fatal series, we note that in South Australia a report on 106 fatal cycle crashes by Longo [2], based on Coroner's files (which rely heavily on investigations by police), identified the following most common types of cycling fatality:

- (a) motor vehicle attempted to overtake cyclist: 27 cases, in 23 of which the motor vehicle rear-ended the cyclist
- (b) cyclist turned or swerved unexpectedly into path of motor vehicle: 24 cases, in 21 of which the motor vehicle and the cyclist were travelling in the same direction
- (c) cyclist ride-out into path of motor vehicle from an intersection: 17 cases
- (d) cyclist ride-out into path of motor vehicle, from a driveway, footway or cycle path: 16 cases
- (e) no other vehicle involved: 6 cases.

Longo's [2] report goes up to 1993, which is why 1994 was selected as the start date for the present series. This method of classification was helpful when going through the present series of fatal cases, though it was not followed exactly.

Turning to Australia as a whole, the Australian Transport Safety Bureau reported in 2006 on deaths of cyclists due to road crashes [3]. Table 6 of [3] classifies according to crash type 221 fatal cyclist crashes in the period 1996 to 2000. Crash types similar to (a), (c) and (d) above were found to be numerically important:

- cyclist and motor vehicle travelling in same direction in same lane, motor vehicle hit the cyclist from behind: 46 cases
- crash at intersection, cyclist and motor vehicle both travelling straight ahead in different directions: 24 cases
- cyclist leaving a footway or verge: 35 cases.

Crashes similar to (b) were not highlighted, except that a supplementary analysis of data for 2001 to 2004 drew attention to teenage cyclists veering sharply into the path of motor vehicles.

### Cyclist fatalities in the TARS database

An examination was made of the textual descriptions in the TARS records of cyclist fatalities in the Adelaide Metropolitan Area for 1994 to 2006. There were 37 crashes in which a cyclist

was killed. Two cyclists were killed in one of these crashes. (In South Australia as a whole, there were 56 pedal cyclist fatalities in this period.) The description in the TARS text field seemed adequate to identify the significant features of what happened. However, as always with such a data source, it needs to be remembered that the cyclist is dead and cannot tell their side of the story. Police may not record contributing factors such as inattention or minor speeding by the motor vehicle driver. No attempt was made to seek other sources of information, such as a report prepared for the Coroner or a newspaper report.

The categories below were generated from the present series. The first two categories correspond roughly to (a) in Longo's list above, and the fourth corresponds roughly to (c) and (d). Having an 'other' category at the end means that the list is exhaustive:

- same direction, motor vehicle into rear of cycle: 7 cases (of which 6 were at night)
- same direction, side swipe: 4 cases (of which 3 involved a truck that was turning left, or was about to). In addition to these cases, there were others in which a truck was turning left, and/or the view to the nearside of a left-turning truck was possibly relevant, and/or the cyclist fell under the wheels of a truck
- cyclist turned or swerved unexpectedly into path of motor vehicle: 4 cases
- cyclist emerged unexpectedly into path of vehicle from an intersection or footway: 13 cases
- involvement of cyclist, or running over of cyclist, was secondary to something else: 5 cases
- single vehicle: 2 cases
- other: 2 cases.

Of the 37 crashes, 32 of them fall into one or more of the following four categories: children (0-15), elderly (60+), at night or truck turning.

There were a number of cases in which the motor vehicle driver had had a number of previous crashes, and it is tempting to surmise that he or she bore some responsibility for the crash. However, drivers with higher numbers of crashes may simply drive more, rather than necessarily being more dangerous drivers.

## Cyclist accidents in the at-scene in-depth database

There were 11 crashes in the at-scene in-depth database, and narrative accounts are included in our full report [1]. We found that they fell into three groups, as follows:

- motor vehicle turning left: 4 cases
  - bicycle from footpath into side of left-turning trailer of truck
  - left-turning truck struck cyclist on its inside
  - car turning left at an unexpected place struck cyclist on its inside
  - left turn by van struck cyclist on its inside

- fast cyclist: 3 cases
  - fast cycle into rear of parked car
  - truck turned right across path of oncoming cyclist; visual obstruction; speed of cyclist
  - fast cycle into rear of stationary car that had intruded into the bicycle lane
- others: 4 cases.
  - car failed to give way to cycle at roundabout
  - cyclist struck by towed caravan as they passed parked vehicle
  - car moved to left at same time as cyclist moved to right
  - cyclist acting as a pedestrian disobeyed red pedestrian light; visual obstruction.

It may also be noted that a visual obstruction was relevant in two cases.

Eleven crashes are rather too few to draw firm conclusions from, but the differences from the fatal series are rather more noticeable than the similarities. We suggest that a way of conceptualising these is that fatalities mostly resemble other accidents, except for (a) a bias towards circumstances in which the motor vehicle is travelling at high speed or the cyclist is frail, and (b) the occurrence of run-over cases (notably involving trucks without side protection).

## Comments

Both the report by Longo [2] and the present series of fatal cases suggest that only a limited number of types of crash need to be addressed. Note, though, that this is probably exaggerated, as we have chosen the central stories that were most frequent among the cases we happened to have; in a different series, random variation is likely to mean that these central stories will not be quite so frequent.

Routine police data on the many cycle crashes that are non-fatal also contributes to the understanding of how cycle safety may be improved in the future. See, for example, Hutchinson, Kloeden and Long [4].

The discussion in section 10 of our full report [1] draws upon the existing literature and includes pedestrian as well as cyclist issues. It examines some conventional countermeasures to pedestrian and cyclist accidents, concentrating on seven topics: night time, drunkenness of pedestrians, visual obstruction by traffic, visual obstruction by roadside objects, possible improvements to other details of the road, trucks (visibility from the cab and side protection), and speed. There is also consideration of the allocation of space to different types of road user (pedestrian, cyclist, motorcyclist, motorist). We emphasise that if society collectively wishes for transport that has the three features of being safe, environmentally friendly (like cycling and walking) and reasonably quick, there needs to be serious consideration given to which modes are compatible with which others and thus can share space, and how much space should be allocated to each.

## Acknowledgements

This project was funded by the South Australian Department for Transport, Energy and Infrastructure (DTEI) through a Project Grant to CASR. The DTEI Project Manager was Peter Watts. CASR is supported by both DTEI and the South Australian Motor Accident Commission. The views expressed in this report are those of the authors and do not necessarily represent those of the University of Adelaide or the funding organisations.

This project relied heavily on the work of the CASR staff who conducted the at-scene in-depth investigations of crashes, and ultimately, on the cooperation of people who provided information about those crashes.

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## Piloting a Safe Cycle education program

by Eddie Wheeler, Secretary/Manager, NRMA – ACT Road Safety Trust, GPO Box 2890, Canberra ACT 2601

An innovative cycling safety education program is being developed and trialled at Melba Copland Secondary School in the ACT with a grant of \$11,980 from the NRMA – ACT Road Safety Trust. The aim is to prepare and deliver a school-based pilot program targeting Years 7 to 10 that will promote bicycling safety when using multi-user paths, on-road cycle ways and roads in the ACT.

The Safe Cycle program was launched at the junior campus of the school on 24 November 2009. As part of the event, Trustee Julie Thornton presented the Trust's ceremonial cheque for its grant to the School's Principal Michael Battenally (see Figure 1).



Figure 1. Eddie Wheeler (Trust Secretary/Manager), Julie Thornton (Trustee), Terry Eveston (teacher and project manager) and Michael Battenally (Principal) with the Trust cheque for \$11,980 at the launch of the Safe Cycle Program

A key element of the program is the training of some Year 10 students as mentors to assist in delivering the program to Year 7 students. Mentoring is well recognised as an educational tool with the capacity to greatly influence awareness and behaviour. The

project also aims to promote a culture of safety for those students undertaking the Road Ready novice driver program in Year 10.

The long-term goal is for the Safe Cycle program to be rolled out across the ACT Government school system as part of the physical education and outdoor education curriculum. Schools using the Safe Cycle program would administer the cost through normal school procedures.

The Safe Cycle pilot program is expected to take 18 months to complete. It is being developed in five stages:

- **Stage 1: Development of a pilot Safe Cycle program.** Staff with bicycle experience (Certificate IV competencies in cycling) will develop the program through consultation with bicycle educators (Cycle Education, Capital Bike Hire) and community organisations (Canberra Off-Road Cyclists). Regard will be given to the Victorian Bike Ed program, aspects of the Road Ready novice driver program and the called Switch-back Kids early intervention program for at-risk youth.
- **Stage 2: Training.** Teaching staff from Melba Copland Secondary School will be trained to deliver the Safe Cycle program. Selected Year 10 students will be trained as peer mentors to assist in the delivery of the program.
- **Stage 3: Delivery of the Safe Cycle program.** The Safe Cycle program will be delivered as a pilot program with the Year 7 cohort, through the physical education and outdoor education curriculum.
- **Stage 4: Evaluation of the success of the program.** Pre- and post-program testing of participants will be undertaken. Surveys of bicycle educator consultants, parents and students will be undertaken to gauge perceived achievements of the program's goals.

- **Stage 5: Evaluation requirements for transferring the Safe Cycle program to other schools.** Strategies will be developed to enable other schools to deliver the program.

Enhancing the safety of cyclists has always been a major priority for the Trust and it has provided in excess of \$533,000 since its creation in 1992. Cycling initiatives funded include the following:

- school educational programs delivered by Pedal Power and the Australian Federal Police to primary school children

- ‘Share the road’ campaigns utilizing television advertising and bus backs
- helmet wearing campaigns
- visibility campaigns utilizing lights and reflective clothing
- a study into cycle crashes that involves interviewing cyclists presenting at the emergency departments of Canberra’s two hospitals.

## Encouraging safer cycling through the NSW *BikePlan*

by Lyndall Johnson and Matt Faber, Roads and Traffic Authority of NSW

In response to the increasing pressures of climate change, traffic congestion and chronic ill-health associated with sedentary lifestyles, governments around the world are looking with increasing interest at active transport solutions. Significant investment is being directed towards cycling infrastructure and encouragement programs in many major western cities [1, 2].

New South Wales is no exception. In May 2010, the NSW Government released the *NSW BikePlan* ([http://www.pcal.nsw.gov.au/\\_data/assets/pdf\\_file/0009/90837/NSWBikePlan\\_WEB.pdf](http://www.pcal.nsw.gov.au/_data/assets/pdf_file/0009/90837/NSWBikePlan_WEB.pdf)), which outlines a comprehensive range of activities to be undertaken over the next 10 years to promote and enhance cycling across the state.

The *NSW BikePlan* focuses on how cycling can help make the towns and cities of NSW more sustainable, easier to get around, safer and better connected. Purpose-built infrastructure has been identified as a key component in encouraging more people to ride their bikes. Examples of work to be undertaken over the next 10 years under NSW Government leadership include:

- completing missing links in Sydney’s regional bike route network where strong growth in cycling is already being experienced, or where major construction works present an opportunity to improve cycling facilities
- completing bicycle networks in and around the ‘River Cities’ serving western Sydney’s areas of high population growth, namely Parramatta, Liverpool and Penrith
- helping councils to provide facilities that extend across local council boundaries and that improve accessibility for short cycling trips to town centres, educational facilities, shops and regional services
- connecting and upgrading off-road cycle links in identified Aboriginal communities
- providing cycle ways as part of all state road projects in country NSW
- progressively completing the NSW Coastline Cycleway
- developing and installing standard bicycle route signage that indicates distance and anticipated trip duration to key destinations

- promoting end-of-trip facilities such as showers and bicycle parking facilities at major trip destinations, including secure cages or bicycle lockers at key transport hubs to encourage integrated transport use.

While the provision of high quality infrastructure is important, infrastructure alone may not be enough to motivate people to ride their bike. Therefore, a range of encouragement programs will also be undertaken, including:

- supporting the roll-out of cycling skills and proficiency courses for adults who want to ride more for transport or recreation
- promoting and supporting local cycling events during NSW Bike Week
- supporting major recreational and touring cycling events
- encouraging and promoting the bicycle tourism industry
- developing best-practice guidelines for local bicycle hire or share schemes
- building and maintaining a comprehensive online source of bicycle information, including a bicycle route-finding facility, an online route sharing and feedback facility, and the ability to create personalised cycle network maps
- making bicycle information accessible to people from non-English speaking backgrounds and to people without internet access.

A key target of the *NSW BikePlan* is to achieve 5 per cent of travel by bike for all trips in Sydney of less than 10 kilometres by 2016. This target is ambitious given the current estimated mode share by bicycle is only around 1 per cent in the greater metropolitan area (i.e., the Sydney, Newcastle and Wollongong conurbation) [3]. The NSW Government is determined to reach this target with the assistance of the *NSW BikePlan*’s proposed investment in cycling infrastructure and encouragement programs.

The NSW Government is equally committed to ensuring that the acknowledged social and health benefits of bicycle riding do not come at the cost of road safety. It will be important to take

action so that an increase in the numbers of bicycle riders is not followed by an increase in bicycle-related road fatalities and injuries. To some extent, road safety research – often referred to as ‘safety in numbers’ – does indicate that more bike crashes is not an automatic corollary of more cycling; in fact, where there is a substantial mode transfer from motor vehicle driving to active travel, the individual risk to each pedestrian and cyclist is reduced [4].

However, the safety of cyclists remains a key concern for the NSW Government, and many of the activities in the *NSW BikePlan* have been designed to increase bicycle safety and promote greater awareness of cyclists’ safety among other road users. These activities include the following:

- supporting cycling courses that enhance on-road riding confidence and courtesy
- promoting activities that motivate cyclists to comply with the road rules
- promoting safe riding practices by training and racing cyclists
- conducting research into key cycling-related issues from which road safety messages and information can be developed
- promoting mutual respect among all road users via advertising campaigns, appropriate enforcement initiatives, and ongoing liaison with key road user industry associations and advocacy groups
- promoting the use of high-visibility safety equipment and clothing by cyclists, including helmet-wearing
- working with local councils to introduce lower speed limits where appropriate

- providing school communities with road safety resources and guidance that will help to develop safe riding skills and habits among children and promote confidence in their carers.

The *NSW BikePlan* is a whole-of-government initiative led by the Roads and Traffic Authority with partners including NSW Health, Transport NSW, Department of Environment, Climate Change and Water, Department of Planning, Department of Education and Training, Communities NSW – Sport and Recreation, Department of Premier and Cabinet, and the Premier’s Council for Active Living. With such strong cross-agency commitment, the NSW Government is confident it can provide a safe, enjoyable and effective cycling environment for the people of NSW.

For more information about the *NSW BikePlan*, visit [http://www.rta.nsw.gov.au/hubpages/hub\\_greentravel.html?hlid=greentravel](http://www.rta.nsw.gov.au/hubpages/hub_greentravel.html?hlid=greentravel).

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# Cycling safety in the Australian Capital Territory

by Peter Thompson, Project Manager at the ACT Department of Territory and Municipal Services

The ACT Government is keen to promote cycling because it improves accessibility, efficiency of the transport system, individual health and urban liveability, and it is important for tourism and the environment. While Canberra has some 2500 km of road, there are nearly 500 km of on-road cycle lanes and approximately 2000 km of off-road paths available for cyclists’ use.

Canberra is admired by communities around Australia as a city of off-road cycle paths, where tourists and visitors can ride in comfort and safety. In addition, Canberra now has an extensive on-road cycle network, which allows commuters to ride a more direct route to their destination.

The ACT Government’s support of cycling is based on the *ACT Sustainable Transport Plan*, which aims to increase the levels of cycling threefold throughout Canberra over the next 25 years. This is to be achieved by the provision of safe cycling routes for

all standards of cyclists, changing community attitudes, improving end-of-trip facilities, integrating transport modes and discouraging the use of private cars. The decision for a person to cycle to their destination is made easier if there is a safe route, travel time is shorter, and there is less of an impact on the hip pocket.

The safety of cyclists is a key issue in the provision of cycling programs and infrastructure. Often cyclists and road users become complaisant, and media safety campaigns are required to assist in the modification of community behaviour.

## Key cycling safety issues

It is recognised that not all cyclists want to ride on off-road paths, and the ACT Government has made a significant investment in the provision of on-road cycle lanes that separate

the cyclists from the traffic. A cyclist travels at a much slower speed than most motor vehicles, and space must be provided so the cyclists can be separated from passing vehicles. The space provided must be a suitable surface kept free of debris if cyclists are going to continue to use these facilities. Often the most significant challenge is provision for the safe movement of cyclists through changes in path conditions – e.g., intersections, roundabouts, driveway crossings along on-road paths, and interchanges between on-road and off-road cyclist pathways.

The safety of cyclists is dependent on their visibility to motorists and other cyclists. Many cyclists travel before dawn and after dusk when visibility levels are at their lowest, putting cyclists at a very high risk. A further safety issue is that cyclists often share the cyclist path network with pedestrians, their dogs, mobility aids and other possibly less-experienced cyclists.

The diversity of environments in which cyclists may find themselves requires a variety of design options for the infrastructure provider to utilise. It also requires cyclists to take a minimum level of responsibility in undertaking to ride on both on- and off-road facilities – i.e., wearing appropriate high-visibility clothing, helmet, etc.

## Current activities

To address the current safety issues regarding cyclists, the ACT Government has undertaken a range of actions:

- Provision of on-road cycle lanes, which afford clearly defined and separated areas to the cyclists from the motorised traffic, as shown to the right of the left-turn lane in Figure 1.



**Figure 1.** Pialligo-Fairbairn intersection. (Photo copyright Pedal Power and reproduced with their permission)

- The on-road lane and its surface must be constructed and maintained to a high level of service – i.e., kept free of debris – if cyclists are going to continue to use the facilities provided. The Act Government has committed to maintaining their on-road cycle lanes by providing regular maintenance checks and regularly sweeping their on-road cycle lane facilities.

- A significant challenge for the ACT Government is the provision of safe environments for cyclists when path conditions change – for example, at intersections, roundabouts, driveway crossings along on-road paths, and interchanges between on-road and off-road cyclist pathways. One of the strategies the ACT Government has recently implemented to increase intersection safety for cyclists is the introduction of green pavement markings. This is shown in Figure 2, where the left lane in the foreground is green and continues straight ahead past the left turn lane for motorists.



**Figure 2.** Pialligo-Fairbairn intersection. (Photo copyright Pedal Power and reproduced with their permission)

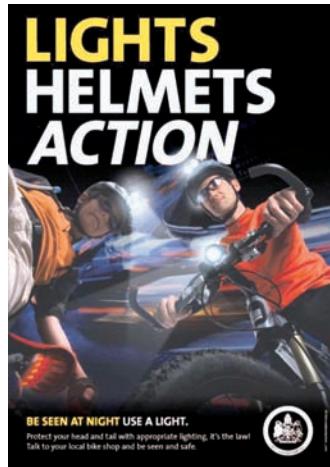
- Another safety treatment utilised by the ACT Government is a restriction zone, which signals to the cyclist a change in path conditions, while also restricting entry to the pathway by motor vehicles. This is illustrated in Figure 3.



**Figure 3.** Cycleway constriction barriers at intersection of off-road cycleway with road

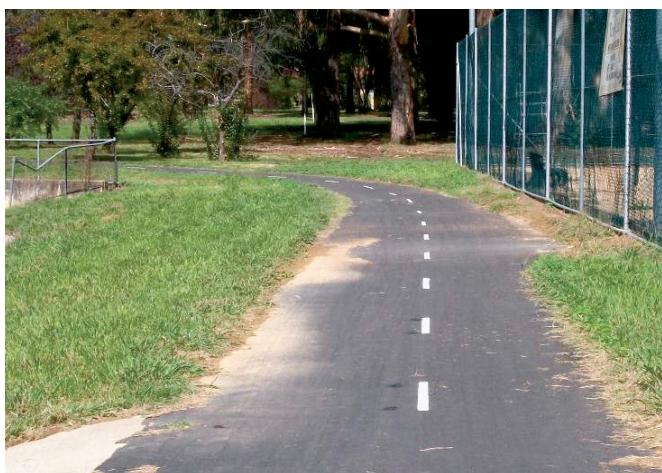
- As many cyclists travel before dawn and after dusk when visibility is low, they require added safety measures. Cyclists are required to have a functioning lighting system on their bike to enable greater visibility of them by other road users. The ACT Government has instigated a media safety campaign to emphasise the use of lights and wearing of

helmets. In conjunction with the media campaign, an enforcement campaign has been launched to assist in cyclist compliance with lighting and helmet use. The 'Lights, helmets, action' poster, as shown in Figure 4, was distributed to ACT bicycle shops and cafes in 2009 and 2010, and is also available for download from the Department of Territory and Municipal Services (TAMS) website [1].



**Figure 4.** 'Lights, helmets, action' poster

- Cyclists predominantly use a shared path environment, whether it is an on-road cycle lane with motorised traffic or an off-road path shared with pedestrians. Each environment has its own requirements of the infrastructure and the cyclist using it. In an off-road shared path environment, the speeds are slower; however, a cyclist's speed is faster than that of pedestrians and delineation assists where sight distance is limited. The ACT Government has included centrelines on cycle paths to aid the safety of all the path users, as shown in Figure 5.



**Figure 5.** Off-road cycle way centreline markings

- As cyclists are permitted to ride on footpaths in the ACT, the ACT Government has developed and installed a cyclist and pedestrian safety sign as a visual reminder to path users that they need to share the space and be mindful of other users. This is shown in Figure 6.



**Figure 6.** Cyclist and pedestrian safety sign

- The ACT Government has introduced a municipal road speed limit of 50km per hour, which has been supported by television and radio advertisements. This form of 'invisible' infrastructure costs virtually nothing, but provides a very high level of safety for all road users, pedestrians through to drivers of larger motorised vehicles.
- The ACT Government has developed design standards for urban infrastructure, *DS13 Pedestrian and Cycle Facilities* [2], to provide consistency in the development of cycleway infrastructure throughout the territory.
- The ACT Government has developed the *ACT Road Safety Strategy and Action Plans* [3], which maintain an ongoing focus on bicycle road safety issues.
- The TAMS website houses the guidelines, strategies, action plans, policies and promotional material that the ACT Government has developed regarding cycling within the territory [4]. All this information is freely available on the website for the community to look at and utilise as needed.

## Future plans

The ACT Government is always looking at ways to improve the safety of cyclists and keeps a keen eye on developments around Australia and the world. Improved cyclist safety is gained by separating cyclists from motor vehicles, and a Copenhagen treatment (a physically separated, on-grade and on-road cycleway treatment) has been considered but not yet been implemented on any project in Canberra.

Speed limits in municipal areas have been reduced to 50 km per hour over the past 10 years, and consideration could be given to further speed reductions in selected areas or throughout the network. This would be consistent with what is happening in other jurisdictions and around the world.

Off-road cycle paths at night provide risk with the increase of cyclists. The provision of some form of lighting on curves and other high use areas will need to be investigated to increase safety.

While a variety of safety measures, both intangible and tangible, have been introduced to the territory by the ACT Government over the past 10 years to increase cyclist safety and encourage yet more cyclists to utilise the infrastructure, more is still planned.

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# Cycling safety in Victoria

by staff of VicRoads, compiled by Juliet Reid, Project Manager, Cyclist and Pedestrian Safety

The Victorian Government is currently making a substantial investment of an additional \$115 million over 12 years towards cycling infrastructure in support of the *Victorian Cycling Strategy* [1], which was launched in March 2009. The strategy has a vision for cycling as a safe, readily available, convenient and preferred transport option for Victorians. It aims to develop and improve bike paths, lanes and other facilities, as well as running campaigns to promote road rules around bicycles and the shared use of Victoria's roads.

Improving cooperation between cyclists and other road users is a key element in increasing road safety for cyclists. The *Victorian Cycling Strategy* includes a priority action to reduce conflicts and risks for cyclists, in the short term, by:

- clarifying the road rules and communicating them more effectively to road users
- building positive attitudes and mutual respect between cyclists and other road users
- developing a guide for local communities to help them conduct bicycle safety campaigns and activities
- conducting a traffic compliance campaign around road rules related to bicycles.

A strong commitment has been made towards road safety with the state government's *Arrive Alive: Victoria's Road Safety Strategy 2008-2017* [2] aiming to drive down the road toll by 30 per cent by 2017. This includes comprehensive measures to improve the safety of cyclists on Victorian roads.

## Key issues for cycling safety

The key road safety issues to be addressed include the following:

- **Education and awareness.** There is a need for relationship building among all road users, in particular for improved recognition of cyclists as legitimate road users.
- **Speed limits.** Studies [3] show that lower speed limits significantly improve safety for cyclists.
- **Infrastructure.** Cycling facilities can be improved to encourage other road users to give cyclists plenty of space on roads or to separate cyclists from other road users.

- **Vehicle safety.** Vehicle design can be improved to reduce the severity of injuries sustained by cyclists in collisions with other vehicles.

## Current activities relating to cycling safety

Victoria has many activities in place or in the planning stages to improve cycling safety. They are described below.

### Cycle network

The Principal Bicycle Network (PBN) is a VicRoads network of cycle routes that provide access to key destinations within the Melbourne metropolitan area. The PBN is one of a number of cycling networks that make up the cycling infrastructure of metropolitan Melbourne.

A review of the PBN is underway to investigate new cycle routes with consideration given to cyclists' preferred travel routes and the SmartRoads planning tool. The review focuses on targeting inexperienced cyclists who may be more cautious road users. There is also an increased emphasis on separating cyclists from motor vehicles where possible, as well as minimising on-road dangers by taking measures such as reducing traffic speeds.

### Space for cyclists

VicRoads recently endorsed profile line marking, which can be placed on the outer edge of a cycle lane to remind drivers to keep clear. Trials in inner Melbourne successfully enhanced cyclist safety [4] and led to an increased use of these locations.

### Safer paths

VicRoads is preparing guidelines for new and existing off-road paths. The guidelines will determine the optimum widths of the paths according to volume of cyclist and pedestrian traffic.

### Cyclist crashes

VicRoads recently commissioned a study entitled *Factors in Cyclist Casualty Crashes in Victoria* [5]. Analysis of police crash

data, hospital admissions and presentations, traffic infringements and coronial data found the following:

- The two most common types of severe crashes were ‘right through’ crashes (occurring mostly where a vehicle approaching from the opposite direction turns right in front of the cyclist) at 13 per cent and ‘intersection cross traffic’ crashes (where a vehicle cuts across the other vehicle approaching from the adjacent direction ) at 9.9 per cent.
- Crashes occurring while emerging from driveway (mainly drivers emerging – 79.7 per cent) and off the footpath (mainly cyclists – 93.6 per cent) accounted for 16.1 per cent of cyclist fatal and severe casualty crashes.
- Only 59 per cent of cyclists were wearing a helmet in cyclist fatalities investigated by coroners.
- Twenty-seven per cent of cyclist fatalities investigated by coroners involved heavy vehicles.
- Only 42 per cent of children aged 0-9 were wearing a helmet in fatal and serious injury crashes reported by police.
- Police reported cyclist serious injury and fatal casualties increased annually by 9.5 per cent and cyclist traffic crashes resulting in hospitalisation increased annually by 10.6 per cent.
- Cyclists seriously or fatally injured were more likely to be aged 30-39 years.

## Safe cycle

‘Safe cycle’ is an annual initiative of VicRoads and the Victoria Police to reduce bicycle collisions and injuries by raising awareness of bicycle safety issues. The 2009 campaign, which focused on using bike lights, wearing helmets and obeying traffic lights, proved successful. Only 4 per cent of cyclists were issued with a penalty notice during the campaign, even in areas with increased levels of surveillance.

## Resources available

In addition to the Victorian Cycling Strategy described earlier, there are numerous resources available to promote and improve bicycling safety in Victoria. These are listed below.

- *Code of Conduct for Training Cyclists* [6] is a brochure developed in partnership with the Victoria Police and the Cycling Promotion Fund to encourage safe riding by cyclists, particularly when riding in groups.
- *Bicycle Helmets – Don’t Ride Without One* [7] is a brochure developed by VicRoads to promote the safe use of cycle helmets.
- The *Victorian Cycling Strategy Report Card* [8] provides details of the first year’s progress in achieving the Victorian Cycling Strategy initiatives.
- *VicRoads Cycle Notes* [9] are a series of design standards for cycling infrastructure intended for engineers, planners and cycling enthusiasts.
- *Bike Ed* [10] is a resource for schools to undertake bicycle training. It contains five modules ranging from ‘Getting started’ to ‘Riding on-road’.

- *Bike Ed Challenge Guide* [11] gives students an opportunity to test their bike riding skills in activities based on the Bike Ed program.

## Future plans relating to cycling safety

To continue to improve cyclist safety, VicRoads is planning to undertake a market segmentation project. The goal is to identify the different types of cyclists to help subsequent communication with cyclists on road safety messages. The three key stages of the project are as follows:

- identifying target groups for segmentation
- developing key safety messages for the different segments
- developing specific tools to communicate the messages to the various segments.

Once the cyclist segmentation project has been completed, VicRoads will develop two campaigns. The first is a ‘Look out for cyclists’ campaign, which will clarify road rules related to bicycles and communicate these to road users. The second aims to build a better relationship between cyclists and other road users, with a focus on responsible cycling and driving and on strengthening the understanding of cyclists as legitimate road users. In the coming months, VicRoads will also develop a bicycle safety community guide to assist local communities in conducting campaigns that focus on cycling safety.

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# The Australian Bicycle Council and the National Cycling Strategy

by Fiona MacColl, Executive Officer, Australian Bicycle Council

The Australian Bicycle Council (ABC) is the national body that manages and coordinates implementation of *The Australian National Cycling Strategy (NCS)*.

Over recent years, Australia has seen a significant growth in bicycle ownership and use. Australians are becoming increasingly aware of the convenience, enjoyment and widespread health and environmental benefits of cycling, and, as a result, initiatives to promote and increase this activity have been incorporated into many government agency programs within the portfolios of Health, Road and Transport, Education, Environment, Tourism, Sport and Local Government.

The NCS has been developed as a coordinating framework identifying responsibilities that lie with the various governments at all levels, as well as community and industry stakeholders, to encourage and facilitate increased cycling in Australia. It sets out actions, with targets, timeframes and resources that will ensure the continued growth of this important component of Australia's transport system.

The vision for the ABC and the NCS is 'more cycling, to enhance the well-being of all Australians', specifically through:

- increasing participation in cycling
- improving safety for cyclists.

## Safety issues

The NCS has six priority actions, each with various required actions. Enabling and encouraging safe cycling [1] is the fourth priority, and requires the actions:

- Monitor and report on crashes involving cyclists, identifying type, number and severity of crashes.
- Support programs and initiatives that promote safe cycling to school and higher education, addressing both infrastructure and facilities requirements and promotional activities.
- Support developing and implementing cycle proficiency and safety programs for primary and secondary school students.
- Support developing and implementing behavioural initiatives that improve cyclist safety, such as programs to increase the conspicuity and helmet wearing by cyclists, and general compliance with road rules.
- Address cycling safety as a component of Black Spot funded works, including the recent history of crashes involving cyclists at relevant locations.
- Support initiatives, including reduced speed limits, that will support safer cycling by reducing motor vehicle speeds.

- Promote the benefits of cycling, using effective and safe routes, to support the National Road Safety Strategy 2001-2010 aim of encouraging alternatives to motor vehicle use to reduce exposure to road trauma.

## Current activities of the ABC

The ABC and its jurisdictional members have completed a number of initiatives over the past five years to increase safety for cyclists, both on- and off-road. A major resource that has recently been completed is the *Austroads Guides* series [2], which have integrated cycling components throughout each of the series guides:

- *Guide to Asset Management* – Part 2
- *Guide to Project Evaluation* – Part 8
- *Guide to Road Design* – various parts
- *Guide to Road Safety* – Part 6
- *Guide to Traffic Management* – various parts.

The ABC has helped to facilitate the development of a national cycle proficiency training program, now called AustCycle [3], that provides a nationally accredited cycle training program for both adults and children, with a particular emphasis on developing road safety skills in participants. Other ABC activities include the development of a research report on *Pedestrian-Cyclist Conflict Minimisation on Shared Paths and Footpaths* [4] with a series of practical factsheets [5] for designers and planners; and endorsement of the Bikeability Toolkit [6] developed by the Bicycle Federation of Australia.

Cycling safety is integral to the promotion of cycling for both pleasure and transport. If cycling is not perceived to be safe, then it is destined to remain a peripheral activity deemed suitable only for the 'road warriors' of society, rather than a mainstream everyday activity or optimal mode of transport.

## Future cycling safety plans for the ABC

Further cycling safety resources and collaborative activities will be developed in conjunction with the next *Australian National Cycling Strategy 2011-2016*, due for release in January 2011. As this next strategy is still in draft and as yet not endorsed, the exact nature of the future cycle safety activities of the ABC cannot be specified. However, it is envisaged that future research and resource development of the ABC, under the auspices of the NCS 2011-2016, will be along similar lines to the current strategy's outcomes to enable increases in cycling participation by the community.

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# The Amy Gillett Foundation 'A metre matters' campaign and other initiatives

by Tony Fox, CEO, Amy Gillett Foundation

What is 'A metre matters' and why is it so important? 'A metre matters' is the current national cycling safety campaign run by the Amy Gillett Foundation that aims to improve awareness of cyclists on our roads.

## The Amy Gillett Foundation

The Amy Gillett Foundation was formed in 2006 after the tragic death of Australian cyclist Amy Gillett, who was hit by a car whilst training with the Australian Cycling Team in Germany. The objective of the Foundation is to decrease death and injury caused by the interaction of cyclists and motorists, and we have created a number of campaigns and programs to help achieve this.

One of the first tasks undertaken by the Foundation was to commission Monash University to compile data on bicycle and motor vehicle crashes, with the aim of better understanding how these accidents occur. Based on police data, this report [1] highlighted a number of pertinent issues:

- The majority of accidents occurred on weekdays (80%) and during peak hour times (56%).
- Most accidents were in daylight (82%) and on dry roads (92%).
- The majority of accidents occurred in situations when motorists should have been aware of the cyclist, with 21% of accidents involving vehicles travelling in the same direction, 28% involving manoeuvring vehicles and 29% involving vehicles coming from adjacent directions at intersections.

This analysis of police data suggested that drivers' lack of awareness of cyclists, and the inadequate space that drivers provide to cyclists on the road, is an important factor in cyclist safety. These findings underpinned the creation of the 'A metre matters' campaign, which asks motorists to provide an extra metre of space on the road for cyclists. See Figure 1. Whilst this campaign requests an extra metre, it is as much about general awareness as it is about specific distance.



With the support of Continental Tyres and a number of media outlets, the campaign has achieved very broad reach to date, including the following national initiatives:

- Television advertising through Channel Ten, OneHD and a number of Foxtel channels
- Cinema advertising through Val Morgan
- Roadside billboards in Melbourne, Sydney and Brisbane (See Figure 2)
- Approximately 6500 'A metre matters' cycling jerseys distributed across all states
- Wide distribution of merchandise products such as car bumper stickers.



Figure 1. Graphic from 'A metre matters' campaign

As a result of this visibility, the campaign has gained significant support, including a petition to the Queensland Government to legislate a metre as the minimum prescribed distance when passing a cyclist, potential council road signs and various online campaigns supporting the program.

## The Amy Gillett Foundation and Monash University PhD scholarship

Research remains the best way of defining what the risk factors are for cyclists on our roads. Whilst there is relevant data and research regarding crash characteristics, very little is known about the causes of these accidents. This is the focus of a research PhD funded by the Amy Gillett Foundation and Monash University, and currently being undertaken by Marilyn Johnson.

Early results of this research highlight the relevance of the 'A metre matters' campaign and the need to improve motorist awareness of cyclists on the road. This research will provide extensive information regarding cyclist - motorist interaction, and this information will form the basis of the next Amy Gillett Foundation road safety campaign.



**Figure 2. Billboard near Brisbane airport promoting 'A metre matters' campaign**

This research is also highlighting that whilst motorist behaviour is a major factor in cyclist accidents, the behaviour of the cyclist also has an impact on whether accidents occur and on the severity of these accidents. Defensive riding skills, adherence to the road laws, using the right equipment and basic respect for other road users all have an impact on cyclist safety. Poor cycling behaviour can have an immediate safety risk, but also a long-term risk if this behaviour creates a bad opinion of cyclists in the minds of motorists, and consequent aggression.

### The AustCycle program

The AustCycle program, jointly owned by Cycling Australia and the Amy Gillett Foundation, is a new program that will

standardize cycling training within Australia and ensure that the highest quality of skill and knowledge development is available to all Australians. Based on the AustSwim model, AustCycle has been trialled successfully in NSW and is now being rolled out around Australia.

Soon all Australians, both young and old, will be able to access a skilled, highly trained, accredited AustCycle trainer, who will be able to teach them everything from bike setup and bike handling skills to road laws and how to ride safely on our roads.

### Conclusion

'A metre matters', PhD research and AustCycle cycling training are just some of the initiatives being undertaken by the Amy Gillett Foundation in our mission to make roads safer for cyclists. Other programs include:

- Road Right – Teaching learner drivers about road rules as they relate to cyclists. For more information, see <http://www.amygillett.org.au/education-road-right>.
- Ride Right – Information about how to buy the correct fitting bike and helmet, plus the relevant accessories. See <http://www.amygillett.org.au/ride-right>.
- 'Remembering Amy' Schools Program – Presentations to school children about cycle safety, general life skills and coping with loss.
- Amy's Rides – Mass participation rides in Victoria, South Australia and ACT, which reinforce correct riding behaviour.

These programs, along with additional programs driven by research findings, will form the front line in the quest to improve the behaviour, awareness and respect of both cyclists and motorists on Australian roads. This will have the long-term effect of making our roads safer for all road users.

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## The politics of cycling and cycling advocacy

by Ashley Carruthers, Pedal Power

Pedal Power's mantra is 'More Canberrans cycling, more often, for a better community'. We are a non-profit organisation with some 3000 members. Our key focus is on advocating for a better cycling infrastructure for Canberra, although the organisation has a diverse range of activities. These include organising rides like Fitz' Challenge and the Big Canberra Bike Ride, offering member services including insurance, maintaining the website, publishing *Canberra Cyclist*, writing press releases and newspaper articles, advising ACT Government on matters related to cycling, and making submissions on cycling provisions for new roads, road upgrades and new building complexes.

The mission of getting more people cycling in the ACT is obviously linked to that of creating safe environments in which to ride, and Pedal Power is committed to the maintenance and development of safe on- and off-road paths catering to the needs of the territory's diverse cycling community. One of our recent safety-related advocacy pushes has been for a blanket 40km/h speed limit in Canberra's town and group centres. We have also been involved in advocacy for pedestrian and bike friendly 'shared surfaces' in the city's commercial zones, and have recently presented government with a well developed plan for a Civic Cycle Loop, a project aimed at making Civic more accessible to people walking and riding bikes.

## Advocacy for safety

By means of its website, e-bulletins and magazine, Pedal Power encourages people who ride in Canberra to note the location of hazards on cycle paths and report these to Roads ACT. In addition to this, Pedal Power is involved in educating its members and other riders in Canberra about riding safely, wearing helmets and making themselves more visible to other road users by having proper lighting and wearing high-visibility clothing.

In everyday terms, Pedal Power comes face to face with cycling safety issues most regularly in the form of poor and even dangerous on- and off-road path design and implementation. A great deal of our time is taken up with commenting on plans for new and upgraded roads and intersections that fail to meet cycling guidelines. Road and path designers and builders all too often unwittingly create danger for people on bikes by doing things like introducing 'slip lanes' that abruptly terminate their priority, providing dangerous crossing points or using unsuitable surfaces.

The unceasing task of commenting on road and path plans is an exceptionally fine and detailed one, but when one steps back from it, the larger issue is that of the co-existence of cars, bicycles and pedestrians. Thus, our work on improving path safety is ultimately about making priority on the road a more equal affair, and making the road a more diverse and mutually respectful place. If one believes in this shared space philosophy, from these things greater safety for all should follow.

When it comes to cycling, we know there is safety in numbers. The more people out on bikes, the more mindful other road users will be of them. Thus, Pedal Power's very mission of increasing numbers of riders is also a mission of increasing safety. In terms of the former, we have undoubtedly been successful. An estimated 85,000 Canberrans cycle regularly. Our annual cordon count in 2010 found cycling into Canberra centre had increased 48% over the past four years, and 64% over the past six years. The on-road paths on Northbourne Avenue, the city's busiest road, are the most heavily used by people on bicycles.

## Redesign of Northbourne Avenue

The ACT Government is currently planning to redesign Northbourne Avenue to make it more amenable to sustainable transport by introducing dedicated bus lanes. Ironically, one scenario is that the on-road cycle lanes might go to make space for the buses. In the course of the public debate about this, the issue of the safety of people riding in on-road lanes on Northbourne Avenue has come up more than once. Pedal Power has taken the position in its press releases that perceptions about the dangerousness of the lanes are in fact not backed up by accident statistics.

We are in favour of the provision of separate off-road paths along Northbourne Avenue – perhaps down the wide leafy median strip, as suggested by the Greens – but we argue that

the on-road lanes should be left in place because they provide a proven safe route for the significant number of faster bike commuters who would be unlikely to use slower off-road paths. There is something of a safety paradox in this issue. On the one hand, on-road riders are perhaps at greater risk of being struck by cars because of minimal separation, while on the other hand, their high visibility on this busy path may have a consciousness-raising effect on drivers, and thus a positive effect on safety.

## Civic Cycle Loop

One of Pedal Power's key safety-related initiatives for 2010 is the Civic Cycle Loop, an innovative 3-kilometre circular route that will connect all of Civic and link into existing and new cycle paths. One of the problems with Canberra's cycle path network is that paths tend to peter out when they arrive at the periphery of town centres. The point of the Civic Loop is to join the dots, thus creating the potential to cycle safely anywhere in Civic within 5 to 10 minutes on the most direct and desirable routes.

Once built, commuters and shoppers will be able to use the Loop to ride into, through and around Civic. Tourists and locals will ideally be able to pick up hire bikes from around the Loop to make quick and convenient journeys. The Civic Cycle Loop will take cycling facilities to a level of European-influenced design not yet seen in Canberra, using as it does the 'second generation' of Copenhagen-style physically separated cycle lanes.

The plan also calls for the redesign of some streets, such as Bunda Street in Civic's heart, as shared surfaces, along the lines of what is being done in Bendigo's CBD. This strategy involves sending cues to drivers that they are in a different and unusual road space where it is appropriate to slow down, and where they should not expect absolute priority. Pedal Power's glossy and informative submission on the Civic Cycle Loop is available on our website [1], and we hope that it might serve as an example to other organisations wishing to lobby for similar facilities in their cities.

## Extended 40km/h speed zones

Another of our recent safety initiatives is the push for extended 40km/h speed zones in Canberra's town and group centres. In 2008, almost a quarter of the casualties on ACT roads involved people on foot and on bicycles (3 dead, 101 injured). Nationally, over one-third of fatal crashes in 2008 occurred in zones with a speed limit of 60km/h or lower. In the year to September 2007, 78 Australians were killed on foot or on bicycles in zones of 50km/h or lower, suggesting that the default 50km/h limit is still too high.

Research indicates a spike in death and serious injury at impact speeds of above 30km/h, with the death rate rising to 45% at 50km/h. While ideally one would like to argue for a 30km/h limit on streets seeing a lot of walking and cycling, it seems unlikely that Australian drivers or governments would find this palatable. For now, 40km/h zones are a workable compromise.

An overwhelming number of cities and towns, both in Australia and overseas, have already adopted 40km/h or lower blanket speed limits. Reduced speed limits are proven to encourage cycling and walking, which provide tangible benefits for health, sustainability and the quality of urban life. Research in Europe and the UK has shown that making cities walkable and rideable even benefits business, since people who commute to retail precincts by these means tend to stay longer and shop more. Lower speed limits are also of course consistent with the shared streets concept, which brings greater safety, diversity and urban vibrancy in its wake. Pedal Power's exhaustive study of this issue is available on our website.

In February 2010 the ACT Government announced that it would trial 40km/h speed zones for Canberra's town centres and shopping centres. Implementation will be over the coming months.

### 'Vision zero' approach

Pedal Power has also been supportive of ACT Chief Minister Jon Stanhope's call for a 'Vision zero' approach for Canberra. 'Vision zero' is a philosophy of road safety first introduced in Sweden in 1997, which establishes the goal of zero deaths or serious injuries in the road transport system. Chief Minister Stanhope called for 'an uncompromising commitment to road safety' in Canberra in a media release of 13 May 2009.

Pedal Power agrees that a targeted reduction of speed limits (and associated enforcement activity) is a good first step in tackling one of the key causes of road trauma. The twin initiatives of the Civic Cycle Loop and 40km/h speed zones will be our key safety related foci over the coming year.

Pedal Power is a diverse organisation incorporating many points of view. However, it is fair to say that all of us on the advocacy committee share the view that we are not in favour of the rigid separation of people on bikes from other road users. We know that people who ride are a diverse bunch, ranging from hardcore roadies and super-commuters to mums and dads pulling child trailers. Some of us are all three at various times! These different modes of cycling require a mix of on- and off-road facilities.

In addition, we can see benefits arising from increasing numbers of people on bikes sharing space on the road with other users. Our vision for safe cycling involves a changed road environment in which significant parts of our cities and towns are low speed zones with high numbers of walkers and people

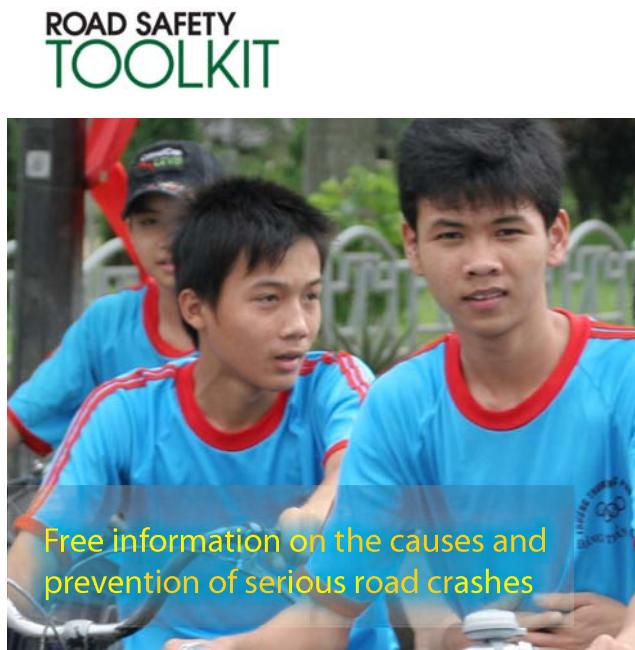
on bicycles. Riding in spaces that are more pluralistic in terms of who is on the road and how they are using it, and in which all road users are mutually aware and respectful of each other, seems to us the best guarantee of riding safely.

While Pedal Power encourages members and all people who ride in the ACT to conform to helmet laws, many of us are private helmet agnostics. If one looks at the extremely low cycle accident statistics for the Netherlands, where cycle commuters almost never wear helmets, it quickly becomes clear that it is the unsafe nature of the Australian road environment that is in fact putting people on bikes at risk.

Those who ride naturally have a responsibility to do all they can to ensure their own safety and that of others, but in an inherently dangerous road environment, they can only do so much. The solution to this is not to retreat from the road, but to advocate for roads designed to create diversity, respect and mutually assured safety.

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# Peer Reviewed Papers

## Crash prediction models and the factors that influence cycle safety

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### Abstract

An increase in cycling in our cities and towns can bring many benefits, including healthier people, reduced emissions from motor vehicles, reduced parking demand and less traffic congestion. A major deterrent to the taking up of cycling, however, is the increased risk of having a crash compared with travelling as a driver or passenger in a motor vehicle. This paper presents research findings from three studies focused on understanding and reducing the risk of on-road cycle crashes.

The first study focuses on the relationship between motor vehicle flow, cycle flow and crashes. The key finding is that as cycle volumes increase, the risk per individual cyclist reduces – the ‘safety in numbers’ effect. The second study focuses on the factors and interventions that influence cycle safety, other than cycle flows. This study involved the development of crash models for mid-block road links in Christchurch, New Zealand, and looks at factors such as provision of cycle lanes, kerbside parking demand, number of access-ways, speed of traffic and presence of a flush (painted) median. The third study, on the effectiveness of cycle facilities at intersections, looks at the relationship between the various cycle facilities installed at traffic signals and crashes. Data on cycle facilities, general road layout (e.g., number of traffic lanes and intersection depth), crash occurrence and traffic flows have been collected at 200 traffic signals in Auckland, Christchurch, Dunedin and Adelaide.

### Keywords

(Bi)cycle facilities, Crash prediction models, Safety in numbers, Safety performance functions

### Introduction

Although there are many guidance documents available for the design of cycle facilities, there is limited research on the

effectiveness of different types of treatments, particularly at intersections. The existing primary source of guidance for cycle planning in Australia and New Zealand is the *Austroads Guideline for Traffic Engineering Practice (GTEP) Part 14*. This guide provides information on the types of facilities that are available, but provides little or no research on the safety benefits of each type of facility.

This paper presents recent research on the safety of cyclists on New Zealand roads. It examines cycle safety on roads with and without cycle facilities and the impact on cycle safety of various road features, including flush (painted) medians and kerbside parking. Finally, it previews research that is in progress to look in more detail at the safety impact of cycle facilities at intersections across New Zealand and Australia.

A number of studies have been conducted to investigate the safety benefits of cycle facilities. Only a limited number of studies consider crash occurrence directly, through before-and-after studies and crash prediction models. Other studies used traffic conflict techniques and risk indices. It is acknowledged by most that the risk of being involved in a crash while cycling is typically higher than while travelling in a motor vehicle, and the key concern is the severity of injuries to cyclists. Research by Jacobsen [1], however, demonstrates that there is a ‘safety in numbers’ effect for cyclists.

Coates [2] performed a before-and-after analysis of crashes at locations where cycle lanes had been marked at mid-block locations and concluded that providing cycle lanes at mid-block locations negatively impacted on crashes at intersections with a very small increase in the number of crashes. This conclusion did not, however, take into account increasing cycle volumes.

Elvik and Vaa [3] found that an advanced stop bar for cycle lanes at intersections leads to a 27% decrease for cycle injury crashes and a 40% reduction in total crashes. In addition, they found that adding cycle lanes through a signalised intersection reduces cycle crashes by 12%, but increases overall crashes by

14%. Construction of grade-separated crossings leads to a major decrease of 30% in total crashes. A summary of further research on this topic can be found in Turner et al. [4]

## Crash prediction models

There is a large body of crash prediction modelling (also called accident prediction modelling or the development of safety performance functions) internationally. Crash prediction models are mathematical models that relate crashes to traffic volume and other road layout and operational features. The majority of this research is focused on the relationship between 'motor vehicle only' crashes (or total crashes) and traffic flows and other predictor variables. There are relatively few studies focused on 'cycle with motor vehicle' crashes, relating these to the volumes of vehicles and cyclists that use an intersection or travel down a route. The development of models for cyclists is hindered by the lack of information on cycle volumes and the location and implementation of cycle facilities.

Crash prediction models are cross-sectional regression models. With crashes being discrete events and typically following a Poisson or negative binomial distribution, traditional regression analysis methods, such as linear regression, are not suitable. The models used in crash prediction are developed using generalised linear modelling methods. Generalised linear models were first introduced to road accident studies by Maycock and Hall [5], and extensively developed in Hauer et al. [6]. These models were further developed and fitted using crash data and traffic counts in the New Zealand context for 'motor vehicle only' crashes by Turner [7].

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

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

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

## Application of crash prediction models

Crash prediction models can indicate how various road layout and operational factors influence the occurrence of crashes and, in this situation, crashes involving cyclists. The models enable us to quantify the effect of various factors, rather than speculate on the level of influence. This is important if we want to understand what factors have the most significant effect on road safety and need to be addressed through interventions.

In terms of cycle safety it is important to determine the key factors that influence the occurrence of particular crash types, so that their effects can be minimised. Such factors include motor vehicle volumes and speeds, and road cross-section. It is also important to understand the safety implications of safety

interventions, such as wider kerbside lanes, removal of parking and provision of cycle facilities on road links and at intersections. The goal is to reduce the crash risk for cyclists to levels that are as close as possible to those of motor vehicle drivers and passengers. Traffic engineers and other professionals can use the results of such research to make decisions and to justify those decisions using evidence of the expected crash savings.

## NZ studies on crash prediction models for cyclists

Research by Turner [7, 8] identified that outside the top three or four major 'motor vehicle only' injury crash types, the next few significant crash types often involved pedestrians or cyclists (the active modes). The proportion of 'active mode' crashes is, however, quite variable, depending on the volume of cyclists and pedestrians using the intersection or travelling along or crossing the mid-block route. Hence traffic signals have a higher proportion of pedestrian crashes than roundabouts, mainly due to most roundabouts being located in areas with low pedestrian demand. Across New Zealand it was found that cycle crashes were a lot higher at roundabouts in Christchurch than at roundabouts in Auckland, because of the much higher number of cyclists in the former.

Since 2000 three studies have been undertaken on crash models for cycle versus motor vehicle crashes. The first study by Turner et al. [9] examined the relationship between crashes and cycle and motor vehicle volumes at traffic signals, roundabouts and mid-block sections. It also looked at crashes involving pedestrians at these three site types. The second study by Turner et al. [4] looked at the effect on cycle safety of a number of road features along mid-block sections, including parking, cycle lanes and painted (flush) medians. The third study, which is still in progress, looks at the safety impact on cyclists of various cycle facilities at traffic signals.

## Data collection

This research has made use of three sample sets. We have referred to these as Study 1, Study 2 and Study 3.

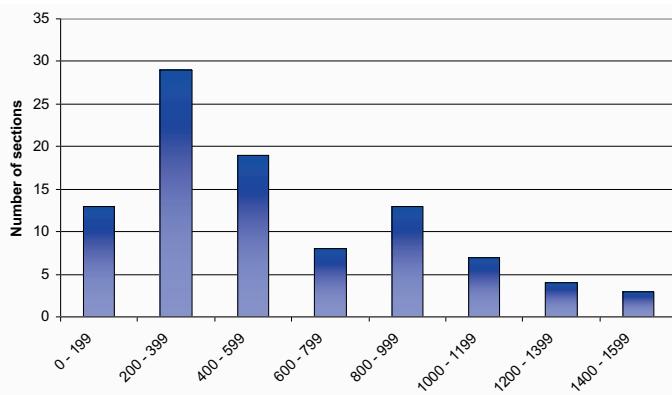
### Sample sets

Study 1 (Turner et al. [10]) focused on the relationship between cycle versus motor vehicle injury crashes, and cycle and motor vehicle volumes. This study included three site types: roundabouts, traffic signals and mid-block sections. The majority of the data was collected from Christchurch, with extra data at intersections from Palmerston North and at mid-blocks from Hamilton. Sites were selected based on the availability of manual turning motor vehicle counts in each city. Table 1 shows the number of sites of each type collected from each city.

**Table 1. Number of sites in each sample set (Study 1)**

City	Traffic signals	Roundabouts	Mid-blocks
Christchurch	97	42	50
Hamilton	0	0	13
Palmerston North	20	3	0
Total	117	45	63

Study 2 (Turner et al. [11]) focused on mid-block locations and the effect on safety of various road features, primarily cross-section factors (e.g., kerbside lane width, cycle lanes, painted medians and parking provision). This study included a sample of 97 mid-block urban sections from Christchurch in New Zealand. This sample included road sections with and without cycle lanes; approximately half had cycle lanes. Almost all routes that had had a cycle lane for at least five years were included in the sample. Figure 1 shows the distribution of lengths of the mid-block urban sections included in the sample. Road sections started and finished 50m back from a major intersection, such as those with traffic signals or a roundabout.



**Figure 1. Mid-block sections by section length (Study 2)**

Study 3 looks at the impact that cycle facilities can have on cycle crashes at traffic signals. A total of 80 sites and 310 approaches are included from three- and four-arm traffic signals in Christchurch. A further 99 sites are to be collected from Adelaide. (See Table 2.) All traffic signals in each city that have had cycle lanes for at least five years, and for which cycle counts were available, were selected for this study. These Adelaide sites have not been included in the preliminary analysis provided in this paper.

**Table 2. Number of sites in each sample set (Study 3)**

Location			3-arm site	4-arm site	Total
Adelaide	Cycle treatment	No	1	6	7
		Yes <sup>a</sup>	12	80	92
		Total	13	86	99
Christchurch	Cycle treatment	No	3	10	13
		Yes <sup>a</sup>	7	60	67
		Total	10	70	80

<sup>a</sup>At least one cycle treatment type was installed on at least one arm of the intersection. Some intersections only have partial cycle treatment.

Crash data for New Zealand sites (those reported to police) were obtained from the New Zealand Crash Analysis System (CAS), a national crash database covering all New Zealand roads.

## Traffic and cycle volumes

Motor vehicle and cycle count data was collected for the various studies from Christchurch, Hamilton and Palmerston North in New Zealand and Adelaide in Australia. These cities were chosen because of the significant numbers of cyclists and the availability of manual cycle counts. For Studies 2 and 3, the focus was on Christchurch and Adelaide due to the numerous cycle facilities that have been installed at intersections and along roads in these cities.

Motor vehicle and cycle counts were obtained in Christchurch from the Christchurch City Council (CCC). The CCC have had a long-term program (in many cases annual) to collect manual turning movement counts (motor vehicle and cyclist) at intersections in the city. They also have a special program for collecting cycle only counts at intersections at less frequent intervals. Where these separate cycle counts are available, they have been used for Christchurch sites, as they have been found to be more accurate (surveyors sometimes miss cyclists when also counting motor vehicles). The other three cities (Adelaide, Hamilton and Palmerston North) also collect manual turning counts at intersections at various intervals – from annually to every three or four years.

The manual turning movement counts were collected (for Studies 1 and 3) on weekdays and during the school term. Motor vehicle counts were typically collected for a one-hour period during the morning (7:00am – 9:00am) and evening (4:00pm – 6:00pm) peak periods. Cycle counts were collected for a one-hour period (and 1.5 hours in some cases) over the morning peak (7:30am to 9:00am) and the evening peak (4:15pm to 5:45pm). The evening peak for some of the sites, however, was observed to be between 2:30pm and 4:00pm, coinciding with the school afternoon peak.

The CCC also collects manual and automated mid-block link counts (motor-vehicles and cyclists). These mid-block counts were used for the mid-block crash models developed in Study 2. Continuous cycle count data at some of the automated count sites was also collected. This was used to study daily and weekly trends in cycle flows.

## Other predictor variables

Data on parking utilisation, presence and width of flush medians, and mid-block speed was collected for Study 2 from field observations and aerial photos. No non-flow predictor variables were collected for Study 1.

Geometry data was collected for the intersection in Study 3, including the number of traffic lanes, traffic and cycle lane widths, lengths of right turn bays and intersection depth. This data was collected using GIS tools and scaled aerial photos. Lane layouts were coded and categorised into 47 types according to the number of turning lanes and the presence of shared turning lanes. Lane layout types and corresponding codes used are depicted in Appendix A. Also in Study 3, the presence and type of cycle treatments on each approach of the

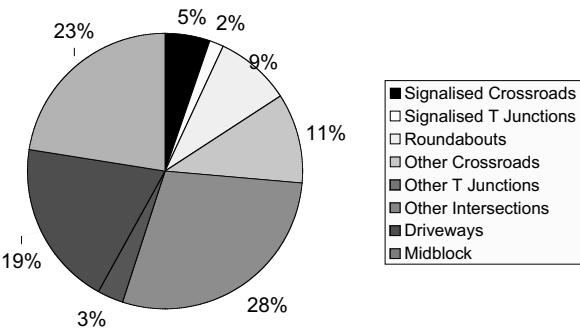
selected intersections were also noted. Cycle treatments were classified according to type, i.e., whether transition, approach, through or departure. Appendix B depicts each of the treatment classifications used in the study

## Data analysis

The major crash types for each form of intersection control and for mid-blocks are presented in this section. Crash prediction models were then developed for these major crash types. The initial data analysis also involved converting raw (counted) traffic and cycle volumes data to representative 24-hour turning movement counts for each intersection.

### Cycle crash analysis

Figure 2 shows the proportion of cycle crashes that occurred at different locations in the road network (traffic signals, roundabouts, etc.) in the period 1999 to 2003 across New Zealand (from Study 1). Figure 2 shows that 42% of crashes occurred on mid-block sections (including driveway crashes) and a further 16% occurred at traffic signals (7%) and roundabouts (9%). The remaining crashes (some 42%) occurred at other intersections, the majority of which have priority control.

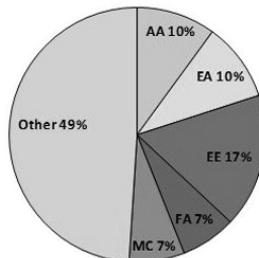


**Figure 2. Cycle crashes by sites type (1999 to 2003)**

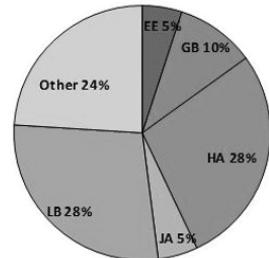
Figure 3 shows the types of cycle crashes that occurred at the different site types in Study 1 for the same five-year period. Figure 3 shows that 'right turn against' (LB – refer to Appendix C) and 'right angle' (HA and JA) crashes are the major types. These crashes involve a cyclist and motorist colliding in the intersection. The majority of the remaining crashes occur on the approach to the intersection. The major crash type at roundabouts involved a motorist entering the roundabout and colliding with a cyclist (consisting of the majority of the observed HA, LB, KA and KB crashes).

Certain crash types were combined for the purpose of modelling, as there were insufficient observed crashes to develop relationships for every crash type. A significant proportion of cycle crashes occur where the cyclist collides with a stationary vehicle or collides with a motor vehicle travelling in the same direction. Crash types A, E, F and G were combined to create a crash model for 'same direction' crashes. Intersecting crashes were represented by models built for HA type crashes, while separate 'right turn against' crash models were built for LB type crashes.

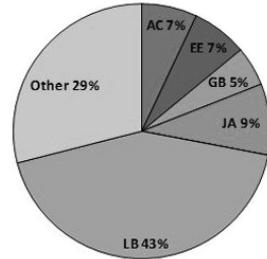
### Cycle crash types at mid-block locations



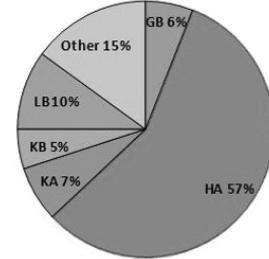
### Cycle crash types at signalised crossroads



### Cycle crash types at signalised T-junctions



### Cycle crash types at roundabouts



**Figure 3. Cycle crashes by crash coding for each site type (refer to coding in Appendix A)**

Table 3 shows the number of reported crashes involving a cyclist at traffic signals, roundabouts, mid-block and other locations during the period 1993 to 2002 for the cities used in Study 1.

### Traffic and cycle volume analysis

The raw volume data was adjusted for hourly, daily and seasonal variations using adjustment factors. Separate factors were used for both motor vehicles and cyclists, as described below, to convert the raw traffic volume data to typical daily flows.

Weekly, daily and hourly correction factors from the *Guide to Estimation and Monitoring of Traffic Counting and Traffic Growth* [12] were applied to the raw traffic count data to determine the Annual Average Daily Traffic (AADT) volume for each turning movement, that is,

$$AADT = \frac{V}{HF} \times DF \times WF$$

where  $V$ =Hourly vehicle counts,  $HF$ =Hourly Factor,  $DF$ =Daily Factor and  $WF$ =Weekly Factor. The flow profile for the study sites for each New Zealand city was assumed to be Urban Arterial Strategic.

The AADT that was used for each movement at each site was the average value of AADT calculated from each set of hourly counts on the survey day. The AADTs were also factored using an annual traffic growth factor to the mid-point of the five-year crash analysis period used to build the crash prediction models.

Correction factors for cycle volumes were calculated using a similar methodology to that adopted for motor vehicles. A term factor representing cycle volume adjustments during each

**Table 3. Cyclist versus motor vehicle accidents, 1993-2002 (row percentages included)**

City	Traffic signals	Roundabouts	Mid-block	Other	Total
Christchurch	259 (15%)	157 (9%)	360 (22%)	898 (54%)	1674
Hamilton	42 (11%)	48 (12%)	75 (19%)	222 (57%)	387
Palmerston North	30 (9%)	38 (11%)	74 (21%)	207 (59%)	349
Totals	331 (14%)	243 (10%)	509 (21%)	1327 (55%)	2410

school term in a year was used in place of the weekly factor. The flow profiles for the study sites in each of the New Zealand cities were assumed to be the combined profiles of commuter and school cyclists.

### Model development

The crash prediction models were developed using generalised linear modelling methods. Minitab macros were used to produce the models from the data collected for each sample set in each of the studies. By way of example, Equation 1 shows an equation from Study 2 for mid-block cycle crashes (crashes between motor vehicles and cyclists).

$$A = 8.60 \times 10^{-3} \times Q^{0.25} \times C^{0.17} \times L^{0.37} \quad \text{Equation 1}$$

where Q is 2-way daily traffic volume, C is the daily cycling volume and L is the segment length.

Further details on the modelling methods, including the various ‘motor vehicle versus cyclists’ models developed and the goodness-of-fit test results, can be found in Turner et al. [11] Also refer to Turner et al. [13] for a more complete summary of the models that have been developed at urban intersections in New Zealand, including traffic signals, roundabouts and mid-block locations.

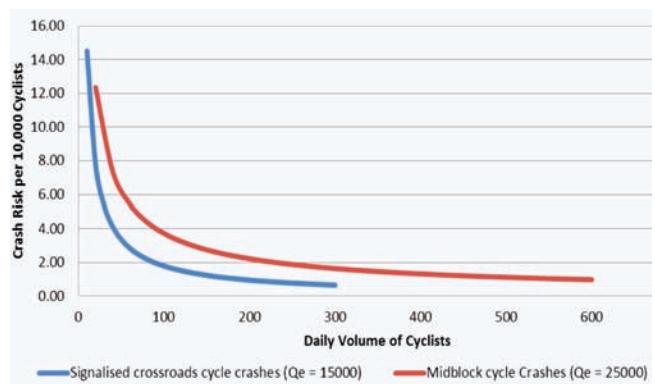
### Modelling results

An examination of the crash prediction models from Studies 1 and 2 can provide insights into how cycle crashes are influenced, both positively and negatively, by various operational and physical variables. The crash relationships are presented here in the form of graphs, figures and reduction rates, rather than mathematical models, so that the results are immediately apparent. While general trends are evident in terms of a positive or negative impact on safety and whether the individual crash risk goes up or down across the range of variables (shown by the shape of the curve), care must be taken when making predictions for actual intersections or links, given the limited number of crashes observed at some sites and the stochastic nature of crashes. Readers should also be aware that the parameter values in cross-sectional models are influenced by the variables that are included in each model (and those that are not) and the correlation between variables.

### Traffic and cycle volumes – the ‘safety in numbers’ effect (from all three studies)

There have now been a number of crash prediction models developed by the research team relating ‘motor vehicle versus cyclist’ crashes to traffic and cycle volumes (flow-only models). The models show a non-linear relationship between crashes and volumes for cycles and traffic. The traffic volume variables tend to have an exponent of around 0.5, indicating a square-root relationship. For cycle flows, the exponent is well below 0.5 and often closer to 0.2 or even 0.1. This low exponent indicates a strong ‘safety in numbers’ effect – i.e., the crash risk per cyclist drops dramatically as cycle volumes increase. This relationship is illustrated in Figure 4 where the modelled crash risk per 10,000 cyclists was found to drop quickly, until starting to level off around 100 cyclists per day for signalised crossroads and closer to 150 cyclists per day on mid-block sections.

This relationship does indicate that cyclists are safer on routes which are well used by other cyclists. It also indicates that cyclists are likely to be safer in cities, towns and parts of urban areas that have a higher proportion of trips by cyclists. This is likely to be due to drivers observing cyclists more regularly and therefore being less surprised when a cyclists crosses their path or is travelling alongside their vehicle. It is also likely that in such towns and cities more car drivers also cycle, and are therefore more aware of cyclists.



**Figure 4. Crash risk per 10,000 cyclists as a function of volume (Qe is entry traffic volume)**

## Link length (for mid-blocks – Study 2)

The relationship between cycle crashes and mid-block section length is also non-linear. A mid-block section (normally an arterial or collector) usually runs from one major intersection to the next, excluding around 50m on each intersection approach (crashes in this section are attributed to the intersection). Alternatively the mid-block section extends to the end of a road. Figure 5 shows the reduction in risk as the mid-block length increases. The reduction is most dramatic from around 100m to 400m where the cycle crash risk drops from 1.5 to around 0.6 crashes (in five years) per 100m. Given that the most common section length is between 200 and 400m (see Figure 1), this is an important crash predictor variable.

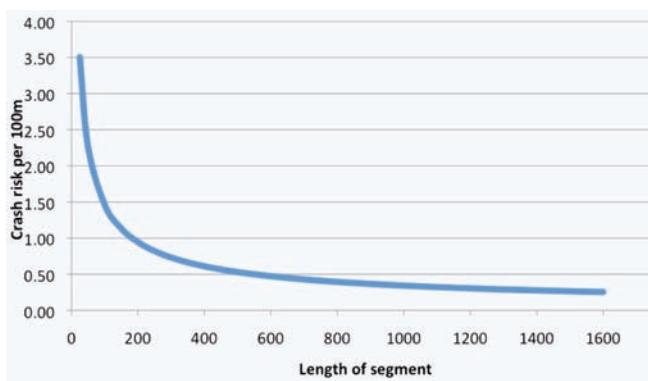


Figure 5. Crash risk per 100m of cycle lane as cycle lane length increases

The shorter mid-block sections often occur in central city shopping areas and other commercial areas around cities and towns, where there are frequent sets of traffic signals. In such environments there is often congestion (at least during morning and evening peak periods), parking turnover is high and it is difficult to provide space for cyclists, either in terms of wider lanes or cycle lanes. It is a complex environment for cyclists. The longer sections tend to occur in suburban areas, where there are fewer intersections and there are fewer impediments to providing wider kerbside lanes or cycle lanes. So it is possible that length does account for a number of variables that do not appear in the models developed so far. Further research is warranted to look at these other variables.

## Vehicle speed (from Study 2)

Vehicle speed was also found to be an important predictor variable. Figure 6 shows that the effect of speed reductions on crashes is greater at lower speeds. A reduction from 40km/h to 30km/h will reduce crashes by around 11%, while a reduction from 50km/h to 40km/h, while still effective, only reduces crashes by around 8.5%. Research on roundabouts by Turner et al. [14] shows a similar relationship for both entry and circulating speeds at roundabouts on entering versus circulating crashes, both for 'motor vehicle only' crashes and 'cycle versus motor vehicle' crashes.

While this result may seem surprising, with a much higher proportion of severe and fatal crashes at higher speed, it shows that the biggest gains are achieved at lower speeds. While some reduction in cycle (and pedestrian) crashes may be possible in dropping speed limits from say 60 to 50km/h, much large gains can be made if we drop speeds to around 30km/h. Even at 50km/h there is still a high risk of a fatal crash, but this drops significantly at speeds of 30km/h. This is a reason why there is a lot of support to reduce speed limits to ideally 30km/h in high pedestrian and cycle areas.

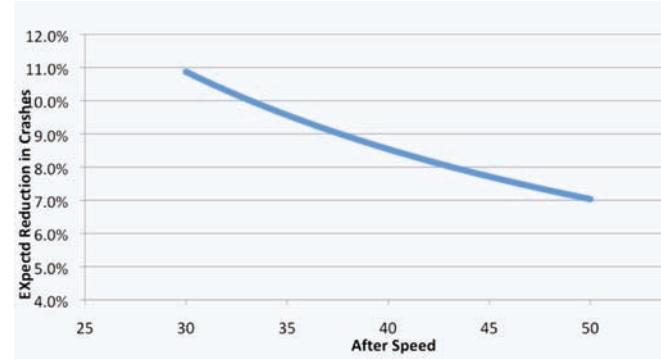


Figure 6. Expected reduction in crashes from 10km/h drop in speed

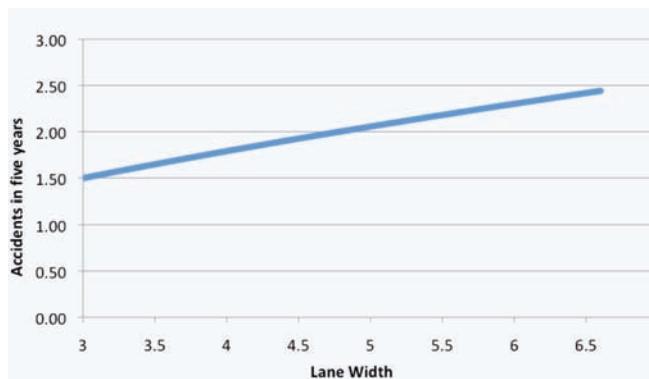
## Road width treatments (from Study 2)

The crash modelling results for the cross-section variables generated some interesting findings that are difficult in some cases to interpret. The key finding that wider kerbside lane widths tended to increase crash rates was not expected. Figure 7 shows the relationship between kerbside lane width and crash rates.

In interpreting this result, the context of these kerbside lanes needs to be considered. Some of the road sections have cycle lanes and other have flush (painted) medians, which effectively reduce the kerbside lane width. While the effect of these variables on crash rates has been assessed in some of the models, a combined model with all the factors has not been developed. So where the kerbside width appears alone with cycle and traffic volume, it is in effect acting as a surrogate for the presence of cycle lanes and flush medians on most of the relatively wide Christchurch roads. Another effect is that roads with wider traffic lanes are more likely to have higher speeds, which may also explain higher crash rates for wider kerbside lanes.

The crash modelling showed that flush (or painted) medians, which are normally installed to reduce 'motor vehicle and pedestrian' crashes (by creating a median for right-turning vehicles and crossing pedestrians), also produce safety benefits for cyclists. A reduction of 37% in crashes when a flush median was present was predicted by the crash prediction models.

The benefit of cycle lanes was mixed, with the crash prediction models showing an increase in cycle crashes. When a before-and-after analysis was undertaken of sites where cycle lanes had



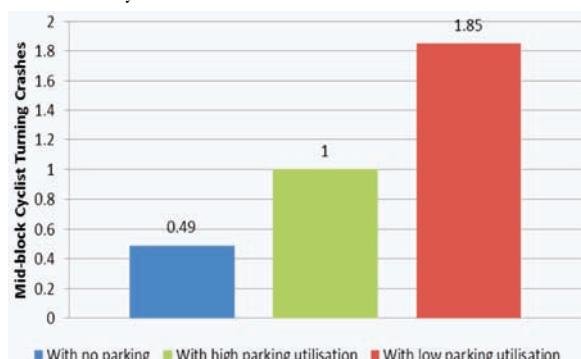
**Figure 7. Relationship between kerbside lane width and crashes**

been installed, however, it was found that there was a 10% reduction in crashes. This seems a little low compared to overseas studies (where reductions of around 20% have been observed) and may be due to some narrower and below-standard cycle lanes being in the sample set. The increase in crashes observed in the crash prediction models was thought to be due to bias in the sites that are selected to have cycle lanes, with cycle lanes more likely to be installed on roads with higher cycle crash rates.

### Parking provision (from Study 2)

The presence and utilisation of parking was found to be an important variable in the models. The absence of parking showed a reduction in cycle crashes of approximately 50% (see Figure 8). In terms of parking utilisation, those sites with relatively high levels of parking tended to have a neutral effect on crash rates. Those sites with low parking utilisation had almost twice as many crashes (85% more) as sites that had higher utilisation of parking.

The most likely explanation for this is that cyclists tend to use the parking shoulder when the parking utilisation is low, but at times have to pass parked vehicles, which creates a potential conflict point with car drivers, who may be taken by surprise. This matter does deserve further research, as does the benefit of painted medians, which may give drivers more space when they encounter cyclists.



**Figure 8. Impact of parking on cycle crash rates**

### Cycle treatments at traffic signals (from Study 3)

An initial analysis of the latest study, using the signalised intersections in Christchurch, produced results which consolidate those found in earlier studies. A crash model with vehicle and cycle flows produced exponents (coefficients 'b' in the earlier specification) for vehicles of 0.5 and for cycles of 0.3, confirming the 'safety in numbers' effect of earlier studies. These changed to 0.65 and 0.2, respectively, when 'right turn against' only crashes are used. This indicates that 'right turn against' crashes decrease more with increased cycle flow for a given vehicle flow than all crashes combined.

A before/after control/impact analysis of the effectiveness of cycle installations, using the empirical Bayes method of Hauer [15] revealed that cycle installations have little effect on the crash rate (for the study period 2001-2005, the expected crash rate without installation was 0.36, while the observed crash rate with installation was 0.34). Painting of cycle lanes, however, was found to be effective. There are a number of other variables that are likely to impact on cycle crash occurrence, including intersection depth (at traffic signals cyclists may get caught in wider intersections when traffic signals change), traffic signal phasing and number of traffic lanes (which means right-turning vehicles have to cross through more traffic to turn right). Each of these variables will be examined in future crash prediction modelling studies.

### Conclusions

There are few studies internationally that have developed prediction (regression) models for crashes involving cyclists. This is despite the potential for such models to improve our understanding of the relationship between cycle crashes and a number of physical and operational variables. Three studies have been undertaken in Australasia, one of which is still in progress. In these studies, data has been collected on crashes, traffic volume, cycle volume and a number of other crash predictor variables (road cross-section, intersection layout, cycle facilities and motor vehicle speed). The studies have examined cycle crashes at traffic signals (around 7% of cycle crashes), roundabouts (9%) and mid-blocks (42%), with more detailed evaluation of traffic signals and mid-blocks.

The crash models produced in these studies have provided an insight into the relationship between cycle crashes and a number of road factors. The strongest relationship is between crashes and cycle and traffic volumes. The crash models show a 'safety in numbers' effect, with the potential for large reductions in crash risk per cyclist as cycle volumes increase. The modelling to date indicates that there are big reductions in risk when flows reach 100 cyclists per day per approach at traffic signals and 150 cyclists per day on mid-block sections. As traffic volumes increase the number of cycle crashes increase, although at a reduced rate.

The crash models also indicate a significant reduction in crash risk as speeds reduce. The reduction in crashes increases as speed lowers. For a 10km/h drop from 50km/h to 40km/h there is around an 8.5% reduction in crashes, while this increases to an 11% reduction when the speed drops from 40km/h to 30km/h. The findings for speed and traffic volumes are consistent with the UK five-step hierarchy of cycle improvements, which favours reduction in traffic volumes and speed before other interventions. The benefit is greater at lower speeds, as it is much safer to reduce speeds down from say 60km/h to 30km/h, than only 50kph, where the risk of a fatal crash is still relatively high.

The findings that crash risk reduces as cycle volume increases should be acknowledged at this stage as simply an association between the two measures. It may be a causal relationship, in that, for example, the increased visibility of a higher cyclists flow prevents accidents that would occur at lower flows. Alternatively, it may be only an association, in that, for example, higher cyclist flows only occur on inherently safer routes. Further research is required to settle this current uncertainty.

Crash rates appear to increase as link lengths reduce. Link lengths tend to be shorter in commercial areas, particularly in the middle of cities, where large intersections are more closely spaced. Hence this variable may be a surrogate for high parking turnover, high traffic volumes and higher densities of access-ways. The research shows that the crash rate for a 400m road link is almost a 1/3 of that for a 100m road link. With a number of road links (in the sample set at least) between 200m and 400m in length, it is important that cycle safety is given significant attention for shorter road links.

The research on road cross-sections so far only provides part of the picture in terms of the best combination of cycle lane, kerbside lane width and provision of a flush median. The findings do indicate around a 10% reduction in cycle crashes when cycle lanes are provided. This is perhaps on the low side, given that the sample set contained some of the older cycle lanes in Christchurch, some of which were of lower standard (e.g., narrower width) than more recent cycle lanes. The study also showed that flushed (painted) islands lead to a 37% reduction in crashes.

The results on lane width actually showed that narrower lane widths were safer. This result was unexpected. Given the form of the model, however, it is likely that the narrower lanes were associated with roads that had cycle lanes or flush medians or both. Hence it indicates that it is better to provide these extra facilities and narrow the traffic lanes, than to leave wide traffic lanes, where speed management is difficult. Further analysis of the data collected should provide more insights.

As shown elsewhere, the removal of parking results in a large reduction in crash occurrence, at around a 50% reduction. When parking is provided, it is better that it be fully utilised. Roads with low utilisation of parking have almost twice the crash rate (an 85% increase) than roads with high utilisation. The most likely reason for this increase is that cyclists utilise the

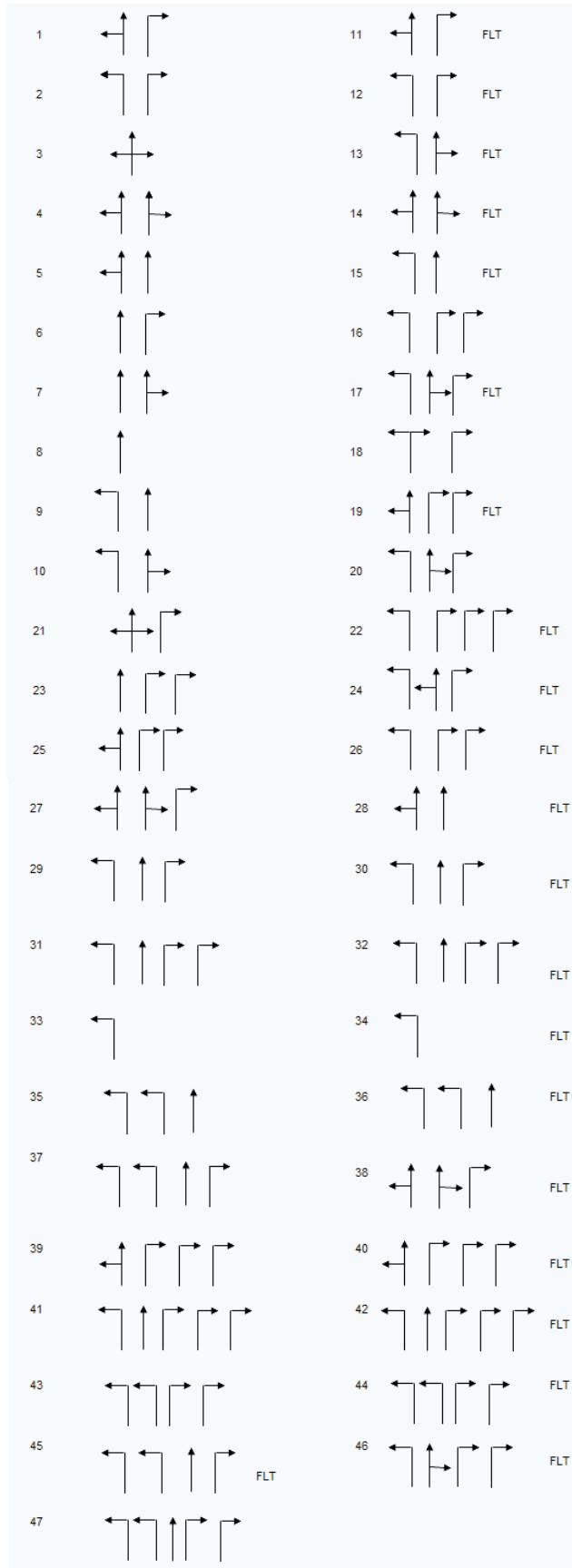
parking shoulder for most of their journey, but at intervals have to pass parked cars. This may in turn create a potential conflict with passing motor vehicles, as the cyclists move out into the traffic lane. An area of future research is to examine how flush medians may provide the extra room that is required for motorists to take evasive action during such events.

A study is currently underway, using a before/after control/impact design with data from signalised intersections in Christchurch and Adelaide, examining the impact of cycle installations on safety. Variables being considered are vehicle flow, cycle flow and design aspects of the cycle installation, as well as the geometry of the intersection. Results will be fully reported in the literature when the study is complete. Current research studies will look at a number of new variables at intersections, including how intersection depth may impact on right angle (or red-light running) cycle crashes; how signal phasing, particularly right turning phasing, may impact on 'right turn against' crashes; and how the number of lanes impacts on crashes involving right-turning cyclists.

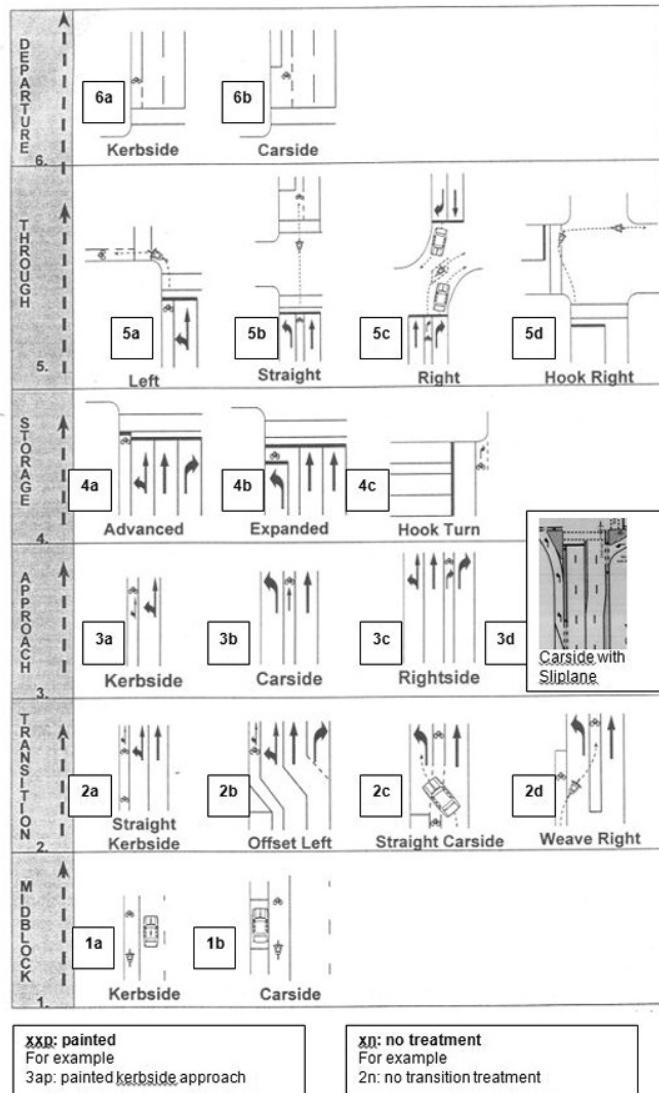
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## Appendix A – Lane layout coding chart



## Appendix B – Cycle treatment chart



## Appendix C – NZ crash collision diagram

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

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

# Cycling injuries in Australia: Road safety's blind spot?

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## Abstract

Cycling rates are relatively low in Australia, but cyclists comprise about 1 in 40 traffic crash fatalities and about 1 in 7 serious injuries. While it appears that cyclists are over-represented in traffic injuries relative to their exposure to injury risk, the magnitude of this excess risk in Australia is currently unknown. The relationship between cycling rates and injury rates over time is also unknown, though the subject of considerable speculation. This paper addresses these two issues, drawing on available traffic injury and travel distance data principally for the greater metropolitan areas of Melbourne and Sydney.

Acknowledging data limitations and the need to interpret findings with caution, the evidence suggests that based on fatality and serious injury rates per kilometre travelled in Melbourne and Sydney, the relative risk of fatality for cycling compared with driving is between 5 and 19. The relative risk of serious injury for cycling compared with driving in Melbourne is 13 based on police data, and 34 based on hospital data, while the relative risk of all injuries (minor plus serious) is 19 in Sydney based on police data. Cyclist injuries appear to be increasing sharply in Melbourne (109% increase from 2000 to 2008), although the picture is less clear in Sydney due to data limitations. We argue that the evidence suggests that while road safety counter-measures have undoubtedly led to a safer operating environment for vehicle occupants, the (arguably) car-centric nature of many of these measures appears to have done little to improve cyclist safety.

## Keywords

Bicyclist, Car occupant, Fatality rate, Injury rate, Relative risk

## Introduction

Cycling rates are relatively low in Australia [1], but cyclists comprise about 1 in 40 traffic crash fatalities [2] and about 1 in 7 serious injuries [3]. While fatalities and serious injuries for car occupants (drivers and passengers) have declined over time, cyclist fatalities have remained steady, and serious injuries have increased [2, 3].

In the six years between 2003 and 2008, traffic-related fatalities for cyclists in Australia ranged between 26 and 43. On average there were 36 deaths per year, representing 2.3% of all road deaths for this time period. Passenger, pedestrian and driver deaths showed average annual decreases of 5.2%, 3.2% and 0.9%, respectively, but no trend was apparent for cyclist deaths [2].

Serious injuries followed a similar pattern. In 2007, pedal cyclists comprised 14.6 percent of serious injuries in road-based traffic crashes in Australia [3]. Over the period 2000 to 2007, based on data from the Australian Institute of Health and Welfare (AIHW) National Hospital Morbidity Database, serious injury rates for cyclists (per 100,000 population) increased by 47%, while for all other modes (motorcycles aside), rates either remained steady or declined [3]. The extent to which the increase in cyclist serious injuries is attributable to increased rates of cycling is currently unknown, though there appears to have been no commensurate increase in bicycle travel in Australia [4, 5].

International comparative data show large variations in cyclist fatality and injury rates between countries [6]. Large variations also occur in the relative risk of injury for cyclists compared with car occupants. A survey of Toronto commuter cyclists found that bicycle accident rates per kilometre cycled were between 26 and 68 times higher than similar rates for car travel, and the authors reported much lower cyclist accident rates for a similar survey conducted in Ottawa, Canada [7]. These large geographical variations in cyclist injury rates and in relative risks for cyclists and car occupants indicate substantial differences in driving/cycling conditions, including road infrastructure and driver/cyclist behaviour.

Substantially lower cyclist fatality and injury rates in countries such as the Netherlands, Germany and Denmark have been attributed to better cycling infrastructure; national cycling education, skills and promotion programs; widespread traffic calming, including lower speed limits (30km/hr) in urban areas; and driver licensing and road safety systems that place greater responsibility on drivers for the safety of cyclists and pedestrians [6, 8, 9].

Christie et al. report a clustering among OECD countries into those that have achieved high rates of relatively safe cycling for young people, and those where cycling rates are low and fatality rates relatively high [9, 10]. Australia currently falls into the latter group of countries – achieving relatively low child cycling fatality rates per child population<sup>1</sup> largely through low and declining levels of cycling [10, 11].

After several decades of declining rates of cycling for transportation purposes (as opposed to social/recreational purposes) in Australia, there are some indications that cycling among adults, particularly in inner city areas, is now increasing, at least in terms of numbers if not per capita rates [4, 12]. In view of the multiple health, environmental, transport and community

liveability benefits of a mode shift from car use to cycling, policies and strategies for increasing transportation cycling have been developed within all levels of government (local, state and federal) across several sectors (health, transport, environment, urban planning and community) [13]. It is important that the substantial benefits of increased levels of cycling are not diluted by increased injury rates. A recent editorial in the *Medical Journal of Australia* recommended action to increase both the prevalence and safety of cycling in Australia [14].

The aim of this paper is to compare the incidence rate and relative risk of cyclist and car occupant casualty crashes in Sydney and Melbourne. First, we address the crucial issue of the computation of reliable injury rates, highlighting the need for an exposure metric based on distance cycled, as well as the practical challenges involved in doing this. Second, we estimate the relative risks, for traffic fatalities and injuries, of cycling compared with car travel based on distance travelled. Third, we explore the relationship between cycling rates and cyclist fatality and injury rates in Sydney in an attempt to examine the ‘safety in numbers’ theory [15] in an Australian setting. The study draws on available traffic injury and travel distance data, principally for the greater metropolitan areas of Sydney and Melbourne.

## Methods

The risk of being injured in an accident is simply the number of injuries occurring per some measure of exposure (e.g., distance travelled, population) and is computed as follows:

$$R_{ijk} = \frac{A_{ijk}}{D_{ijk}} \quad [1]$$

where

$A$  = annual number of injuries

$D$  = exposure (annual distance travelled, population, etc.)

$i$  = demographic grouping

$j$  = mode of transport (car, public transport, bicycle, etc.)

$k$  = situational circumstance (time of day, speeding, etc.).

The implications are that computation of injury rates requires a) a source of crash/injury information and b) a comparable (across time and space) source of travel/exposure information.

From a road safety perspective, the two metrics of exposure most widely used are i) population/per capita and ii) kilometres of travel. Per capita exposure is appealing because it is easy to derive, it gives the actual number of people (per capita) affected, and it is broadly comparable across risk contexts (e.g., road safety, cigarette smoking) and countries.

However, it has two serious limitations in the context of the current paper. First, it does not indicate the magnitude (i.e., time, distance) spent exposed to a particular risk situation, which is highly variable across demographic/modal sub-groups. Second, when running relative comparisons between (say) car

occupants and cyclists, use of a single ‘population’ metric will tend to underestimate the risk to cyclists by virtue of the fact that the actual ‘at risk’ population of cyclists is much lower than car occupants (ideally one would need the population of car occupants, population of cyclists, etc., to run the relative comparison). Kilometres of travel (potentially) overcome both these issues, but the main downside is that there are relatively few sources of such data and the data requirements are much more demanding, particularly when analyzing small sub-groups such as cyclists.

## Police-reported crash data (TADS and CrashStats)

In New South Wales, the main source of crash information is the Traffic Accident Database System (TADS) maintained by the Roads and Traffic Authority [16]. TADS provides detailed information of all accidents reported to the police involving one moving road vehicle on a public road in which a person was killed or injured or at least one motor vehicle was towed away. Within the TADS database, a fatality is defined as someone who dies within 30 days of an accident as a result of injuries sustained in the accident, while an injury is defined as a person who is injured as a result of the accident but who did not die within 30 days of the accident. Injuries are not differentiated by severity.

In Victoria, the main source of crash information is CrashStats, which is maintained by VicRoads and provides summary information relating to all traffic collisions reported to Victoria Police. Fatalities are defined in the same way as TADS, but injuries are differentiated into serious injuries and minor injuries. Serious injuries are those requiring hospital treatment and possibly admission. CrashStats data from 1987 to 2009 are available through the Internet [17].

## Hospital-reported crash data (VISU - Victoria)

Road user injuries for residents of the Melbourne Statistical Division (MSD), which covers the Greater Melbourne Metropolitan Area, were provided by the Victorian Injury Surveillance Unit (VISU), which is the injury subset of the Victorian Admitted Episodes Data Set covering all admissions to Victorian hospitals. Data on traffic accidents for car drivers, car passengers and cyclists were provided for the financial year 2007-08 (1 July 2007 to 30 June 2008) to enable comparison with police-reported CrashStats data for this year (the most recent available). In VISU, traffic accidents are those occurring on a ‘public highway’, which is defined as ‘land open to the public as a matter of right or custom for purposes of moving persons or property from one place to another’, and includes bike paths and cycle ways.

## Travel data

While Australia has not embraced a national travel survey since the early 1970s, most of the major cities have conducted or are conducting regional travel surveys including the two largest cities, Sydney and Melbourne. In the case of Sydney, the

Sydney Household Travel Survey (SHTS) has been running since 1997 [18]. The SHTS is a continuous survey (covering all days of the year) of around 5000 households per annum drawn from the Sydney Greater Metropolitan Area<sup>2</sup>, providing a unique longitudinal database for studying travel trends.

In Melbourne, the Victorian Activity and Travel Survey (VATS) was conducted from 1994-1999 for the Melbourne Statistical Division (Greater Melbourne Metropolitan Area), and data from the more recent Victorian Integrated Survey of Travel and Activity (VISTA) are available for the period from May 2007 to June 2008. Both VATS and VISTA are continuous surveys that cover all days of the data collection period (like the SHTS), but they are not directly comparable, so longitudinal data are not available at present for Melbourne.

### Computation of fatality and injury rates and relative risk

For Sydney, five calendar years of TADS data were made available from 2002 to 2006, while six financial years of SHTS data were available from July 2001 to June 2007. To ensure compatibility, four financial years were used in the analysis, 2002 (corresponding to 1/7/02 – 30/6/03), 2003, 2004 and 2005, and crashes were selected for the Sydney GMA to match the area covered by the SHTS data. Injuries were derived from the TADS by age/gender groupings for four travel modes – namely, motor vehicle, motorcycle, bicycle and pedestrian.

The SHTS data were manipulated to provide weighted person kilometres of travel by the age/gender/modal groupings using five years of pooled data up to and including the current financial year. SHTS (five-year pooled) data for 2006 show that the average total distance travelled per day was 32.2 km, comprising 26.6 km (81.8%) by car and 0.11 km (0.3%) by bicycle. Injury data for cyclists and car occupants (drivers and passengers) from TADS and travel data from SHTS were used to calculate injury rates based on distance travelled.

For Melbourne, travel data for the period May 2007 to June 2008 were obtained from the VISTA 07 Summary Report [19]. The average daily total distance travelled by all surveyed household members (11,400 households in the Melbourne metropolitan area), together with the proportion of distances travelled by car and bicycle, were used to estimate the total number of kilometres travelled by car and bicycle in Melbourne for the 2007-08 financial year. VISTA data show that the average total distance travelled per day by householders in the Melbourne metropolitan area during 2007-08 was 33km, comprising 28.2 km (85.4%) by car and 0.26 km (0.8%) by bicycle. Distances were similar for the total sample, which included metropolitan Melbourne and regional Victoria. This corroborates recent evidence showing that cycling levels are around double in Melbourne compared to Sydney [20].

Comparable data from VATS for 1994-99 are not currently available, so it is not possible to document changes over time in bicycle and car travel distances in Melbourne.

Injury data for cyclists and car occupants (drivers and passengers) from VISU and CrashStats for the Melbourne Statistical Division for the financial year 2007-08 were used to calculate injury rates based on distance travelled.

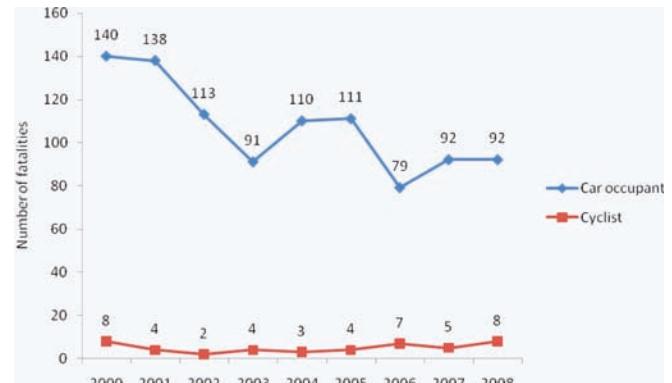
Relative risk was used in this study to indicate the risk of a cyclist being killed or injured relative to a car occupant. It was computed by dividing the relevant rate for cyclists by the relevant rate for car occupants.

## Results

Results are calculated and presented separately for Melbourne and Sydney. Trends in fatalities and injuries for car occupants and cyclists are presented, followed by fatality and injury rates, and relative risks (bicycle:car) of fatality and injury.

### Melbourne fatalities

Based on VicRoads CrashStats data, fatalities for car occupants in the Melbourne metropolitan area (Melbourne Statistical Division) decreased between 2000 and 2008, while cyclist fatalities show no apparent trend (Figure 1). For the years 2000 to 2008, cyclists and car occupants (drivers and passengers) comprised 2.8% and 59.7%, respectively, of road fatalities in the Melbourne metropolitan area. For the financial year 2007-08 there were four cyclist fatalities in the Melbourne metropolitan area (Table 1).



**Figure 1. Cyclist and car occupant road traffic fatalities, Melbourne metropolitan area, 2000 to 2008**  
(Source: VicRoads CrashStats online)

### Melbourne serious injuries

For the Melbourne metropolitan area, VicRoads CrashStats data show that cyclist serious injuries increased from 201 in 2000 to 421 in 2008, an increase of 109%. Over the same time period (2000 to 2008), the proportion of police-reported serious injuries among cyclists increased from 4.7% to 8.2%, while the proportion of serious injuries among car occupants decreased from 69.5% to 64.9% [17].

Injury data for the year 2007-08 from both CrashStats and VISU (Table 2) show that the number of police-reported serious cyclist injuries is substantially lower than the number of hospital-

**Table 1. Fatality risk for cyclists and car occupants in the Melbourne metropolitan area**

Data source	Financial Year	Fatality count		Average daily distance travelled (2007-08) <sup>a</sup>		Fatality rate (per 10 <sup>8</sup> km)		Relative risk (Bicycle: Car)
		Car occupant	Bicycle	Car occupant	Bicycle	Car occupant	Bicycle	
Crash Stats	2007-08	96	4	101,322,600	934,180	0.26	1.18	4.54

<sup>a</sup>Based on MSD population of 3.593 million on 30 June 2008.

**Table 2. Serious injury risk for cyclists and car occupants in the Melbourne metropolitan area**

Source of injury data	Year	Serious injury count		Average daily distance travelled (2007-08)		Injury rate (per 10 <sup>8</sup> km)		Relative risk (Bicycle: car)
		Car occupant	Bicycle	Car occupant	Bicycle	Car occupant	Bicycle	
VISU	2007-08	3488	1075	101,322,600	934,180	9.4	315.3	33.5
Crash Stats	2007-08	3538	440	101,322,600	934,180	9.6	123.5	12.9

reported serious injuries. This finding is consistent with other Australian studies [21]. One of the primary reasons for the difference is likely to be that CrashStats data is focused on on-road accidents, whereas many cycling injuries occur on bike paths and cycle ways. These locations are included as ‘traffic accidents’ in VISU, but are probably less likely to be reported to police.

While the number of police-reported serious cyclist injuries is substantially lower than the number of hospital-reported serious injuries, this is not the case for car drivers and passengers, where police-reported and hospital-reported serious injuries are similar (Table 2).

### Melbourne fatality and injury rates and relative risk

In the Melbourne metropolitan area in 2007-08, the fatality risk for a cyclist travelling the same distance as a car driver or passenger was four and a half times that of a car occupant (Table 1). This relative risk needs to be interpreted cautiously as annual cyclist fatalities are low and highly variable. For example, for the *calendar year* 2008, there were eight cyclist fatalities in the Melbourne metropolitan area, which would have resulted in a relative risk of nine times that of a car occupant. The cyclist/car occupant relative risk based on distance travelled was substantially higher for serious injuries than for fatalities: 34 based on VISU injury data and 13 based on CrashStats injury data (Table 2). This is due to the hospital database (VISU) recording about two and a half times the number of serious cyclist injuries than the police database (CrashStats). This finding is consistent with other Australian studies, which have also reported large differences in police and hospital records of serious cyclist injuries [21].

### Sydney fatalities

In the Sydney GMA, fatalities for car occupants declined by 9% between 2002 and 2005, while cyclist fatalities show no apparent trend (Figure 2). For the years 2002 to 2005, cyclists and car occupants comprised 3.1% and 51.4%, respectively, of road fatalities in the Sydney GMA.

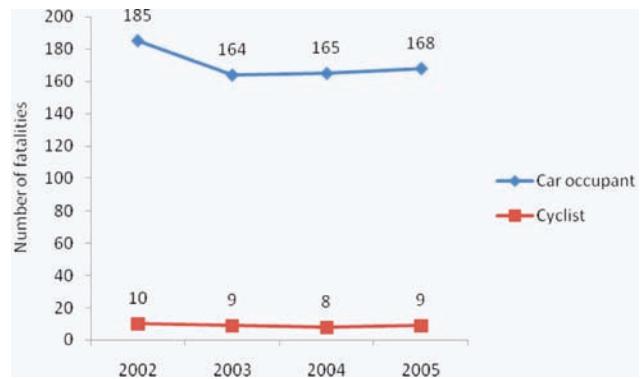


Figure 2. Cyclist and car occupant road traffic fatalities, Sydney metropolitan area, 2002-2005 (Source: TADS data)

### Sydney serious injuries

For Sydney, over the period for which TADS data were made available (i.e., 2002-03 to 2005-06), injuries declined by 1666 (-10%) for motor vehicle occupants and 66 (-6%) for cyclists (Figure 3).

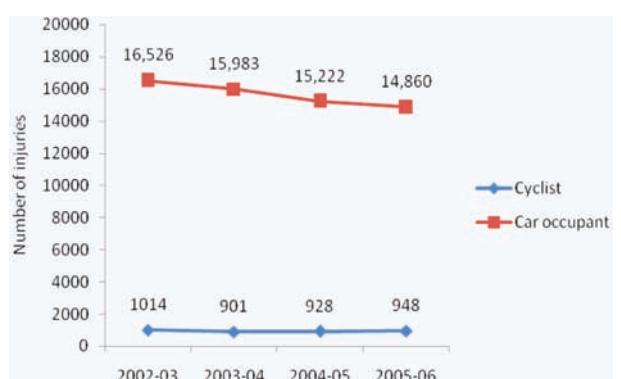


Figure 3. Number of injuries, bicyclists and car occupants, Sydney metropolitan area

## Sydney fatality and injury rates and relative risk

Over the period 2002-2005 the SHTS data show that kilometres travelled by car occupants increased by 7% (Table 3). Over the corresponding period, bicycle kilometres of travel increased by 29%, but this should be interpreted with caution due to low cycling trip numbers. Each wave records around 20,000 car occupant trips and 250 bicycle trips, so using five-year pooled data implies around 100,000 car occupant trips and 1250 bicycle trips.

Over this four-year period, injury rates declined for car occupants (Table 4). Injury rates appear to have decreased for bicyclists, but as noted above, these data need to be interpreted cautiously. Nevertheless, even allowing for sampling issues, the relative risk of injury on a bicycle is around 13-19 times higher than in a car over the four-year period, which is broadly comparable to the results from Melbourne based on CrashStats data. Again, interpreting results with caution, it also appears that fatality risk may be greater for cyclists in Sydney, with more cyclists killed despite cycling rates of around half those of Melbourne. Note that because injuries include minor as well as serious injuries, the injury rate figures cannot be directly compared to those for Melbourne.

## Discussion

Road safety improvements in Australia since the 1970s have been substantial [2]. However, these improvements have not been equitably distributed across all road user groups, with

cyclists in particular experiencing a higher burden of fatalities and serious injuries than car occupants after adjusting for distance travelled. The traffic-related fatality and serious injury rates for cyclists in this study are high in comparison with many other wealthy countries [6, 22].

While sample sizes preclude a direct comparison with other locations, the cyclist fatality rate of between 4 and 7 per  $10^8$ km in Sydney<sup>3</sup> is several times greater than in the Netherlands (1.1 per  $10^8$  km), Denmark (1.5) and Germany (1.7), though comparable to the USA (5.8) [6]. The cyclist serious injury rate in Melbourne of between 124 (police data) and 315 (hospital data) per  $10^8$ km cycled<sup>4</sup> is very much greater than in the Netherlands (14), Denmark (17) and Germany (47), though, once again, comparable to the USA (375) [6]. A recent analysis reported a killed or seriously injured cyclist casualty rate of 54 per  $10^8$ km in Britain in 2008 based on police crash reports [22].

The ‘safety in numbers’ theory has been proposed as a possible explanation for these large international differences in cycling fatality and injury rates [15], but countries and cities with high levels of safe cycling also have far better conditions for cycling. It is likely that good cycling infrastructure, policies that treat cycling as a legitimate form of transport, lower urban speed limits, national driver and cyclist education, skills and training programs, and stricter levels of liability for drivers in car/cyclist interactions [8] all contribute to improved cyclist safety [6].

The large difference in cycling safety between Australia and many other wealthy nations, as well as the large and increasing

**Table 3. Fatality risk for cyclists and car occupants in Sydney GMA (2002-2005)**

Year	Fatality count		Average daily distance travelled (5-yr pooled)		Fatality rate (per $10^8$ km)		Relative risk (Bicycle: car)
	Car occupant	Bicycle	Car occupant	Bicycle	Car occupant	Bicycle	
2002	185	10	121,983,414	487,687	0.42	5.62	13.52
2003	164	9	122,087,060	360,147	0.37	6.85	18.60
2004	165	8	130,962,527	452,459	0.35	4.84	14.03
2005	168	9	130,262,321	630,420	0.35	3.91	11.07

**Table 4. Injury<sup>a</sup> risk for car occupants and cyclists in Sydney GMA (2002-2005)**

Year	Injury count		Average daily distance travelled (5-yr pooled)		Fatality rate (per $10^8$ km)		Relative risk (Bicycle: car)
	Car occupant	Bicycle	Car occupant	Bicycle	Car occupant	Bicycle	
2002	16,526	1,014	121,983,414	487,687	37.12	569.64	15.35
2003	15,983	901	122,087,060	360,147	35.87	685.41	19.11
2004	15,222	928	130,962,527	452,459	31.84	561.92	17.65
2005	14,860	948	130,262,321	630,420	31.25	411.99	13.18

<sup>a</sup>For Sydney, TADS records all injuries, including serious and non-serious

gap between cyclist and car occupant safety in Australia, suggest that there may be a ‘cycling blind spot’ in road safety in Australia. Interventions that reduce speeding, drink and drug driving, fatigue, and distracted driving potentially benefit all road users. However, other ‘passive’ traffic safety measures, such as seat belts, air bags and safer vehicle interior design, while of benefit to car occupants in the event of a crash, are of no benefit to vulnerable road users such as cyclists, pedestrians and motorcyclists. In addition, some factors that improve the safety of motor vehicle occupants may actually increase the risk to vulnerable road users (e.g., larger and heavier vehicles, bull bars) [23]. It has also been argued that ‘as people in cars are made to feel safer, the standards of driving experienced by those on the outside decline’ [24].

Cyclists, as well as car drivers, are largely responsible for their own safety and the safety of other road users. Nevertheless, road safety strategies that are based on the ‘Vision zero’ principle [25, 26] acknowledge that road conditions are not always optimal and that road users who occasionally make mistakes should not have to pay for their mistakes with their lives or their health. Passive road safety measures such as seat belts, air bags and safer car interior design are not available to cyclists, who are therefore more dependent on external conditions and the behaviour of other road users.

While road conditions affect both driver and cyclist safety, road hazards can have a greater impact on cyclists because bicycles, unlike cars, are single-track vehicles. It is important to acknowledge these basic differences, rather than ‘blaming’ cyclists for what are often perceived to be erratic or dangerous behaviours. It seems that in Australia, there is a low tolerance for cyclist mistakes and relatively little protection when they occur. A key factor for cyclist safety is vehicle speed, but Australia’s urban speed limits are high by international standards [27], and the safety of cyclists and other vulnerable road users is afforded a lower priority than the achievement of small improvements in motor vehicle travel time [27, 28].

Another factor that may be contributing to the ‘cycling blind spot’ in road safety in Australia is the lack of reporting of cyclist serious injuries to the police as identified in this study and in other Australian studies [21]. In Victoria, the organisations with the principal responsibility for road safety (Victoria Police, VicRoads and the Transport Accident Commission) may be more aware of road user serious injury data reported in CrashStats (police records) than in VISU (hospital records). This might in turn contribute to underestimating the magnitude of serious injuries among cyclists.

Cyclist serious injuries that do not involve a motor vehicle (and are therefore less likely to be reported to police), such as falling off the bicycle, hitting an object, or colliding with a pedestrian or animal, tend to be labelled as ‘cyclist mistakes’. Poor cycling infrastructure can also contribute to these types of cycling accidents. As noted above, single-vehicle serious injuries among car occupants are more likely to be reported to police, and the

contribution of road infrastructure to single-vehicle accidents is well-recognised.

International experience demonstrates that cycling safety can be improved markedly using the same sort of strategic planning that has been used to improve safety for car occupants [6]. Improved cycling conditions that are likely to contribute to increased cycling safety include:

- more extensive, high quality and well-maintained cycling infrastructure, including separated cycling facilities
- basing priority systems on needs of vulnerable road users (where appropriate), rather than car occupants
- improved interactions between cyclists and drivers in the form of mutual respect, courtesy and willingness to share public road space
- education and training for drivers and cyclists aimed at improving skills, attitudes and behaviours
- urban speed limits based on human tolerance to injury in collision with a motor vehicle
- placing greater responsibility for traffic safety through the legal system on those road users who have the potential to cause the most harm to others.

This study aimed to answer some important questions related to cycling safety in Australia. As indicated in the text, some findings are relatively robust, but others are uncertain. In particular, it is not clear whether increased cycling participation accounts for the increases in cycling injuries that have occurred in recent years in Australia and in Melbourne. Sydney was the only location where longitudinal injury and cycling distance were available, but the findings were constrained by small sample sizes. A longitudinal, custom-designed survey of cycling accidents and travel behaviour is probably the best way to answer this important question definitively. In addition, the causes of cyclist injuries in Australia are not well-understood, and further research in this area should be a priority for road safety research.

## Conclusions

While road safety counter-measures have undoubtedly led to a safer operating environment for vehicle occupants, the (arguably) car-centric nature of many of these measures has in fact done little to improve cyclist safety. Cyclists appear to be over-represented in terms of fatalities and serious injuries relative to their exposure to traffic, but under-represented in interventions aimed at reducing traffic fatalities and injuries.

Our attempts in this paper to document the magnitude of and trends in cycling injuries can be categorised as ‘problem-focused’ research, and while we acknowledge that more research is needed to better understand ‘the problem’, there is nevertheless sufficient evidence and a good case for ‘solution-focused’ research and ‘solution-focused’ action. International experience demonstrates that cycling can be made safer [6].

Strategies that have been implemented successfully overseas should be modified, trialled and evaluated in Australia so that the benefits of improved road safety in Australia are extended to all road user groups, thereby addressing the strategic objective of the Australian National Road Safety Strategy of 'Improving equity among road users' [29].

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## Notes

1. Child cycling fatality rates per km cycled are not known.
2. The Sydney GMA comprises the Sydney and Illawarra Statistical Divisions and the Newcastle Statistical Subdivision, which extends from Port Stephens in the north to Shoalhaven in the south to the Blue Mountains in the west.
3. The Melbourne rate was low (1.2 per  $10^8$ km) for the year 2007-08, but cyclist fatalities in Melbourne vary considerably by year.
4. The wide range is due to the use of different injury data sources.

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# Child cyclist traffic casualties: The situation in South Australia

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## Abstract

Data are presented on characteristics of child pedal cycle casualties (as recorded by the police) in South Australia for the period 2001-2004, and how they have changed over the longer period 1981-2008. The factors considered in this paper include site and events, characteristics of the cyclist, and characteristics of the motor vehicle and its driver.

## Keywords

Cyclist safety, Child cyclist injury, Severity of injury, Accident statistics, Bicycle accidents, Pedal cycle accidents

## Introduction

The purpose of this paper is to describe certain characteristics of child pedal cycle crashes in South Australia. The paper is fairly broad in scope, but there is some emphasis on variables that are not often tabulated as a matter of routine rather than on those that are often found in statistical yearbooks. The presentation of the detailed results will be split into (a) the pedal cyclist and the circumstances of the crash, and (b) the motor vehicle and its driver. First, though, Table 1 places child cyclist casualties in the context of cycle casualties as a whole, and shows how the distribution of ages has changed between 1981-1984 and 2005-2008.

Over recent decades, policy changes relevant to helmet use and vehicle speeds have affected cycling patterns and safety. Wearing of helmets by pedal cyclists was promoted from November

1985, and has been compulsory since mid-1991. According to Marshall and White [1], this probably led to both reduced cycling and reduced injuries among the majority who continued to cycle. More recently, there has been a trend towards lower speed limits. Person trips per day in Adelaide were 3.4 million in 1986 and also 3.4 million in 1999, of which the numbers by bicycle were 0.089 and 0.040 million, respectively [2]. The South Australian government is trying to encourage safe cycling, and aims to double cycling trips by 2015 [3]. These trip numbers are in the context of a population of about 1.1 million in the Adelaide Metropolitan Area, and about 1.5 million in the state of South Australia.

In this paper, a description of the methods and tables is followed by two sections of results and a discussion. Most of the tables of data refer to the period 2001-2004, though Table 1 and the comments in the 'Discussion' section concerning trends over time have been updated to 2005-2008. Data for 2001-2004 is included in Table 1 for consistency with the other tables. For further tables (of adult cyclist casualties as well as child), see Hutchinson, Kloeden and Long [4-8]. An earlier version of this paper was presented at a conference held in 2007 [8].

## Methods

This is a retrospective review of police reports of road crashes involving pedal cyclists aged 5 to 15 years for the period 2001-2004 recorded in the Traffic Accident Reporting System (TARS). Police reports of pedal cycle crashes substantially

**Table 1. Pedal cycle casualties in South Australia: Comparison of the distribution of rider age (percentages, of those of known age) in 1981-1984, 2001-2004 and 2005-2008**

Cyclist age group (years)	Percentage in each age group (any severity of injury)			Percentage in each age group (those killed or admitted to hospital)		
	1981-1984	2001-2004	2005-2008	1981-1984	2001-2004	2005-2008
0-15	44.8	15.6	11.6	51.8	21.7	16.5
16-19	13.7	8.2	6.9	10.2	6.8	7.2
20-29	19.7	22.8	22.1	16.7	19.6	19.7
30-39	9.2	20.4	22.1	7.6	15.3	19.7
40-49	4.2	17.8	19.6	3.9	18.3	16.1
50-59	3.5	9.8	11.3	2.8	11.9	11.2
60-99	4.9	5.3	6.6	7.0	6.4	9.6
Total number <sup>a</sup>	2440	1605	1750	684	235	249
Total number <sup>b</sup>	2678	1819	1938	742	253	266

<sup>a</sup>Excluding those of unknown age    <sup>b</sup>Including those of unknown age

understate the totality of pedal cyclist trauma: many cyclists are hurt without a motor vehicle being involved, and for these, hospital records are a better source of information.

Nevertheless, for crashes that do involve a motor vehicle, and especially for information about the crash circumstances and the motor vehicle, police reports are the best source of routinely collected data.

Postcodes are used to describe the location of the crash. These are grouped as 5000-5099 (this is centred on the city of Adelaide and has a boundary between 8 and 16km from the centre of Adelaide), 5100-5199 (outer Metropolitan Adelaide), 5200-5999 (the rest of South Australia). The intention is not chiefly to compare the postcode groups, but rather to classify by site variables, vehicle variables and so on, within the different postcode groups, as questions may arise as to relative frequencies of different categories in downtown Adelaide, the outer suburbs of Adelaide and country South Australia.

Most tables refer to all casualties, and also the subset who were killed or admitted to hospital (termed ‘serious’). Note that any finding about differences in the proportion of seriously injured casualties potentially has at least two interpretations: either one group does tend to be less seriously injured, or the minor crashes in that group are more likely to be reported to the police than in the other group. Casualties of unknown age were excluded from the tables. In 2001-2004, these accounted for some 11.8 per cent of the total (and for casualties who were killed or admitted to hospital, the proportion was 7.1 per cent).

## Results: The cyclist and the crash circumstances

Among child cyclist casualties, males outnumber females about 6 to 1 (Table 2). The distribution of ages is skewed towards the older children (Table 3).

Tables 4 to 7 tabulate the following variables, respectively: whether or not the accident took place at a junction, speed limit, the nature of the site and crash type. Casualties occur in approximately equal numbers at and away from junctions (Table 4), and very largely on roads where the speed limit is 60km/h or lower (Table 5). Several traffic engineering features at a site may be of interest, singly or in combination – speed limit, whether there is a junction, whether the road is divided, complexity of the junction and nature of traffic control. In Table 6, these factors have been combined in a way intended to give a useful summary of the site – not too little detail, and not so much that it is overwhelming. As to crash type, those termed ‘right angle’ were the most common (Table 7). Types of crashes are devised with motor vehicles chiefly in mind. Further, an appreciable number of crashes are complicated or do not fall easily into one category or another.

From Table 5, the proportion of child casualties killed or admitted to hospital was 20 per cent when the speed limit was 60km/h or less, and 35 per cent when the speed limit was 70km/h or higher.

There are about the same number of casualties per day on weekends as on weekdays. The times of day when casualties are

**Table 2. Numbers of pedal cycle casualties aged 5-15 in South Australia 2001 to 2004, by postcode group of crash and rider sex**

Cyclist sex	All severities			Total	Of whom, these numbers were serious			Total		
	Postcode group				5000-5099	5100-5199	5200-5999			
	5000-5099	5100-5199	5200-5999							
Male	106	60	48	214	19	8	14	41		
Female	17	8	10	35	3	0	7	10		
Total	123	68	58	249	22	8	21	51		

**Table 3. Numbers of pedal cycle casualties aged 5-15 in South Australia 2001 to 2004, by postcode group of crash and age group of casualty**

Cyclist age group (years)	All severities			Total <sup>a</sup>	Of whom, these numbers were serious			Total		
	Postcode group				5000-5099	5100-5199	5200-5999			
	5000-5099	5100-5199	5200-5999							
5000-5099	5100-5199	5200-5999		5000-5099	5000-5099	5100-5199	5200-5999			
5-7	5	6	7	18	1	2	5	8		
8-12	57	28	34	119	13	4	11	28		
13-15	61	34	17	112	8	2	5	15		
Total	123	68	58	249	22	8	21	51		

<sup>a</sup>Classifying the casualties by years of age (5, 6, ..., 15), the 249 casualties were split as follows: 8, 6, 4 (totalling 18), 12, 17, 29, 23, 38 (totalling 119), 35, 41, 36 (totalling 112)

**Table 4.** Numbers of pedal cycle casualties aged 5-15 in South Australia 2001 to 2004, by postcode group of crash and road geometry

Road geometry	All severities			Total	Of whom, these numbers were serious			Total		
	Postcode group				Postcode group					
	5000-5099	5100-5199	5200-5999		5000-5099	5100-5199	5200-5999			
Junction	62	30	29	121	13	3	9	25		
Not at junction	57	35	24	116	9	5	11	25		
Unknown	4	3	5	12			1	1		
Total	123	68	58	249	22	8	21	51		

**Table 5.** Numbers of pedal cycle casualties aged 5-15 in South Australia 2001 to 2004, by postcode group of crash and speed limit

Speed limit (km/h)	All severities			Total	Of whom, these numbers were serious			Total		
	Postcode group				Postcode group					
	5000-5099	5100-5199	5200-5999		5000-5099	5100-5199	5200-5999			
40-60	114	55	48	217	20	7	17	44		
70+	3	9	5	17	1	1	4	6		
Unknown	6	4	5	15	1			1		
Total	123	68	58	249	22	8	21	51		

**Table 6.** Numbers of pedal cycle casualties aged 5-15 in South Australia 2001 to 2004, by postcode group of crash and the nature of the site

Speed limit (km/h), whether at junction, and details	All severities			Total	Of whom, these numbers were serious			Total		
	Postcode group				Postcode group					
	5000- 5099	5100- 5199	5200- 5999		5000- 5099	5100- 5199	5200- 5999			
0-60, no junction, divided road	19	8		27	4	1		5		
0-60, no junction, not divided road	36	22	19	77	5	3	7	15		
0-60, junction, traffic signals, T- or Y-junction	3	1		4	1			1		
0-60, junction, traffic signals, crossroads	10	3	1	14	2			2		
0-60, junction, priority, T- or Y-junction	30	19	11	60	6	3	4	13		
0-60, junction, priority, crossroads		15		13	2		4	6		
0-60, junction, roundabout	2	2	3	7	1			1		
70+, no junction	1	4	4	9		1	3	4		
70+, junction	2	5	1	8	1		1	2		
Other and unknown	5	4	6	15			2	2		
Total	123	68	58	249	22	8	21	51		

**Table 7. Numbers of pedal cycle casualties aged 5-15 in South Australia 2001 to 2004, by postcode group of crash and crash type**

Crash type	All severities			Of whom, these numbers were serious				
	Postcode group			Total	Postcode group			Total
	5000-5099	5100-5199	5200-5999		5000-5099	5100-5199	5200-5999	
Rear end	6	5	1	12	1		1	2
Hit fixed object	2	2		4				
Side swipe	14	8	7	29	3	2	1	6
Right angle	83	46	45	174	12	3	17	32
Head on	5	3	3	11	1	1	2	4
Roll over	1	1		2			1	1
Right turn	7	1	1	9	2	1		3
Hit parked vehicle	2	1	1	4	1			1
Hit object on road	1			1				
Other	2	1		3	2			2
Total	123	68	58	249	22	8	21	51

most frequent are those when most children are travelling to or from school: the hours beginning 08, 15, 16 and 17. See Hutchinson, Kloeden and Long [4] for details. The hourly pattern is different at weekends and in school holidays, as might be expected.

## Results: The motor vehicle and its driver

For the data discussed in this section, the crashes have been restricted to those in which there was a single motor vehicle and a single pedal cycle. The numbers of casualties are consequently slightly fewer in Tables 8 to 10 (concerning the type of vehicle, the sex of its driver and the age of its driver, respectively) than in other tables.

Cars and car derivatives make up at least 82 per cent of the total (Table 8). Of motor vehicle drivers whose sex was known, males made up 56 per cent (Table 9). The age of the motor vehicle driver is quite evenly distributed, except for ages over 60 (Table 10).

Considering the severity of injury, cars (including car derivatives) and other vehicle types were involved in the relative proportions 100:19 for serious casualties, but 100:8 for total casualties. Vehicle age has little effect on the proportion of child casualties killed or admitted to hospital; the proportion was 19 per cent when the motor vehicle dated from the 1980s, 22 per cent when it dated from the 1990s and 20 per cent when it dated from the 2000s.

From Table 9, the proportions of child casualties killed or admitted to hospital were 27 per cent for male drivers and 9 per cent for female drivers of the motor vehicle.

Following up that rather surprising difference, Table 11 gives data for 1985 to 2004 (the period 1981 to 1984 was excluded because the percentage of seriously injured casualties was higher

then). What is shown in each of the eight cells is the percentage of pedal cycle casualties aged 5-15 who were killed or admitted to hospital.

It might be asked whether the apparent differences in Table 11 are statistically significant. A straightforward approach to statistical testing would lead to the conclusion that the effects of sex, age and speed limit are all significant. However, a straightforward approach is not necessarily correct. For one thing, the three factors might interact: it appears in Table 11 that the combination of the vehicle driver being male and the speed limit being high leads to particularly high probabilities of serious injury. For another, there is often a greater degree of variability in crash data than is implied by the usual assumptions [9].

## Discussion

We should first repeat our earlier reservation that while police reports are the best source of routinely collected data concerning cyclist collisions with motor vehicles, casualties do occur without being reported to the police, particularly when no motor vehicle is involved.

Those aged 0-15, as a proportion of total pedal cyclist casualties, have fallen from 45 per cent in 1981 to 1984, to 12 per cent in 2005 to 2008 (Table 1). Child pedal cyclist casualties reached a maximum in about the period 1982 to 1987 and have fallen sharply since. In 2005 to 2008, the average annual number of pedal cyclist casualties aged 5-15 had fallen to 19 per cent of the number in 1981; and in the case of the seriously injured, to 11 per cent. Those seriously injured, as a proportion of total pedal cyclist casualties aged 5-15, fell from 34 per cent in 1981 to 21 per cent in 2005 to 2008. Similarly, those killed, as a proportion of total pedal cyclist casualties aged

**Table 8. Pedal cycle casualties aged 5-15 in South Australia 2001 to 2004: Number in single motor vehicle vs. single bicycle crashes, by postcode group of crash and type of motor vehicle**

Type of motor vehicle	All severities			Of whom, these numbers were serious			Total	
	Postcode group	Total	Postcode group	Total	Postcode group	Total		
	5000-5099	5100-5199	5200-5999		5000-5099	5100-5199	5200-5999	
Car <sup>a</sup>	99	52	42	193	16	6	15	37
Other	6	3	7	16	1	1	5	7
Unknown	12	9	6	27	4	0	0	4
Total	117	64	55	236	21	7	20	48

<sup>a</sup>Cars and car derivatives**Table 9. Pedal cycle casualties aged 5-15 in South Australia 2001 to 2004: Number in single motor vehicle vs. single bicycle crashes, by postcode group of crash and sex of motor vehicle driver**

Sex of motor vehicle driver	All severities			Of whom, these numbers were serious			Total	
	Postcode group	Total	Postcode group	Total	Postcode group	Total		
	5000-5099	5100-5199	5200-5999		5000-5099	5100-5199	5200-5999	
Male	54	30	40	124	13	4	17	34
Female	54	29	14	97	3	3	3	9
Unknown	9	5	1	15	5	0	5	
Total	117	64	55	236	21	7	20	48

**Table 10. Pedal cycle casualties aged 5-15 in South Australia 2001 to 2004: Number in single motor vehicle vs. single bicycle crashes, by postcode group of crash and age of motor vehicle driver**

Age group of motor vehicle driver	All severities			Of whom, these numbers were serious			Total	
	Postcode group	Total	Postcode group	Total	Postcode group	Total		
	5000-5099	5100-5199	5200-5999		5000-5099	5100-5199	5200-5999	
16-19	5	5	3	13	1	1	1	3
20-29	22	7	11	40	4	0	3	7
30-39	18	15	12	45	3	2	5	10
40-49	16	12	8	36	2	2	5	9
50-59	20	6	6	32	1	1	2	4
60-69	6	4	6	16	1	1	4	6
70-99	3	1	1	5	0	0	0	0
Unknown	27	14	8	49	9	0	0	9
Total	117	64	55	236	21	7	20	48

**Table 11. Single motor vehicle vs. single bicycle crashes in South Australia 1985-2004: Percentages of pedal cycle casualties aged 5-15 who were killed or admitted to hospital, within each combination of categories of sex of motor vehicle driver, age of motor vehicle driver, and speed limit**

Speed limit	Sex and age of motor vehicle driver <sup>a</sup>			
	Male		Female	
	16-29	30+	16-29	30+
0-60	28	24	27	19
70+	52	48	17	31

<sup>a</sup>Cases for which driver age (most commonly) or the other variables were unknown were omitted in constructing this table. As unknown information occurs disproportionately for minor injuries, the percentages here are higher than they would otherwise be.

5-15, have fallen from 2.1 per cent in 1981 to 1984, to 0.0 per cent in 2005 to 2008. A multi-hospital study in the U.K. [10] found a very substantial reduction in the probability of death of injured young people admitted to hospital over the period 1989 to 1995.

In 2001 to 2004, the percentages seriously injured were 18, 12 and 36 for postcode groups 5000-5099, 5100-5199 and 5200-5999, respectively; and 44, 24, and 13 for age groups 5-7, 8-12 and 13-15, respectively [4, 8]. The differences between age groups are very considerable; however, it is questionable whether this measure of severity of injury (largely referring to admission to hospital) is one that can really be compared across age groups, as being admitted to hospital may have different implications for younger children than for older children.

Concerning sex differences (Table 2), it is easy to speculate that boys cycle more and cycle more dangerously, but it is difficult to find supporting evidence for this. However, there is evidence from Toronto that boys both cycle more than girls and have more accidents per hour cycling [11]. Reviewing all forms of unintentional injury of children, Schwebel and Gaines [12] concluded that sex differences had a number of causes – the personality traits of boys as compared with girls, the expression of these traits in behaviours, the circumstances in which the behaviours took place – and both innate and learned factors played a part.

It seems likely that speed is the reason that the motor vehicle driver being male, the motor vehicle driver being young and the speed limit being high, all tend to increase the cyclist's severity of injury (Table 11). If this is true, it should also be reflected in a higher severity of injury in crashes occurring in similar circumstances to cyclist crashes – pedestrian crashes might be included among these.

The trends over time that have been noted demonstrate much progress in reducing trauma to child cyclists. However, part of this reduction is surely due to less use of the bicycle for travel and less use of the bicycle for play. Some people are uneasy that so many children are driven everywhere rather than walking or cycling independently, and that so much of children's time is screen time rather than active time. The policy of the South Australian government to encourage cycling is for reasons of health as well as sustainability [3]. It will be necessary to be on guard against a consequent future rise in cyclist deaths and injuries.

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# The effects of bicycle helmet legislation on cycling-related injury: The ratio of head to arm injuries over time

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## Abstract

Legislation for the mandatory use of bicycle helmets is a controversial issue. The analysis presented in this paper examines the ratio of cycling-related head injuries to arm injuries using hospital admissions data in New South Wales. The analysis is based on the idea that even if the numbers of cyclists has dropped over time, the relative injury rates (head versus arm) should remain unchanged unless some factor is differentially impacting on one type of injury – for example, helmet use reducing head injuries, but not affecting arm injuries.

Results indicate that there was already a fall in the ratio of head to arm injuries before the mandatory helmet legislation was introduced in 1991. After the introduction of bicycle helmet legislation, there was a continued but declining reduction in the ratio of head injuries relative to arm injuries for most age groups. It is likely that factors other than the mandatory helmet legislation reduced head injuries among cyclists.

## Keywords

Injury prevention, Cyclist injuries, Head injuries, Hospital data, Bicycle helmets, Legislation

## Introduction

While the health benefits of cycling are generally agreed upon [1], the risks associated with cycling are a more contentious issue. One early analysis calculated that the benefits of cycling outweighed the risks by a ratio of 20:1 [2]. Methods of calculation of risk vary considerably, from the number of people hurt or killed while cycling, to the rates of morbidity or mortality per million kilometres cycled [3, 4].

In New South Wales (NSW) in the fiscal year 2005-06, there were 2737 serious land transport injuries among people cycling, and there were 16,147 serious injuries to all road users in the same period [5]. Seven people in NSW were killed while cycling in 2006 [6]. Across Australia, 93.3% of all traffic-related cycling injuries occurred in children aged 5-17 years [5]. However, it is difficult to accurately assess the risks associated with cycling without a clear denominator. For example, the number of cycling-related hospitalisations within a given time period needs to be considered in the context of how many people cycled during that period or how far they cycled or for how long.

Head injuries are the most common cause of bicyclist fatalities and serious disability [7], which, in Australia has led to mandatory helmet legislation. Legislation for the mandatory use of bicycle helmets is a controversial issue internationally [8-10], with different research methodologies such as case-control studies and population-based studies reaching different conclusions [11]. Australia and New Zealand are the only two countries in the world with mandatory adult helmet use laws, introduced in Australia for adults on 1 January 1991 and for children under 16 years from July 1991.

Advocates for helmet use cite evidence from bio-mechanical tests and case-control studies that repeatedly show that helmets protect against impact to the head [12, 13] if worn correctly [14]. Anti-helmet advocates claim that mandatory helmet legislation has reduced the number of people cycling and that this has led to reductions in cycling-related injuries attributed to the legislation. The reduction in numbers of people cycling may have actually increased the risk to the remaining cyclists because of Smeed's Law and the 'safety in numbers' hypothesis [15]. Further, they argue that the debate over what impact protective helmets may provide is a distraction from the main bicycle-related health issue – namely, the safety of the bicycling environment [16] – and that cost-benefit analyses do not support mandatory helmet use [16, 17].

This paper seeks to investigate the impact of the mandatory helmet legislation on head injuries in New South Wales (NSW), Australia, by examining the ratio of cycling-related head injuries to arm injuries. The analysis is based on the idea that even if the numbers of cyclists has dropped over time, the relative injury rates (head versus arm) should remain unchanged unless some factor is differentially impacting on one type of injury – for example, helmet use reducing head injuries, but not affecting arm injuries. Arm injuries were chosen rather than leg injuries, as arm injuries are more closely located in relation to the upper torso and head.

## Method

Data on hospital separations in New South Wales were obtained from the NSW Inpatients Statistics Collection (now known as Admitted Patients Data Collection) from 1988-89 (the earliest year data were available) to 2007-08 [18]. In 1998-99 the system used to code this data changed from ICD9 to ICD10, with two years of injuries being coded using both

sets of definitions. For this paper we have used ICD10 coding, and mapped ICD10 codes onto ICD9 codes for data before 1998-99.

External causes of hospitalisations referring to pedal cyclists were selected as cases using ICD10 codes V01.00-V19.99 [19]. These data include all cyclist injuries, not only those involving road traffic [20].

The data were categorised according to principal diagnosis using ICD10 codes. Only codes representing head injuries and arm/hand injuries were used in the study (see Table 1). Cases that had both head and arm injuries were counted in each group. For data from records that used ICD9 codes, cases were selected by mapping codes from ICD10 to ICD9 [20]. The years for which both ICD9 and ICD10 were used (1998 to 2000) indicate that the ratio of head to arm injuries was higher using the ICD10 codes.

All data were tabulated using Microsoft Excel 1997. The ratio of head to arm/hand injuries was calculated by dividing the number of head injuries by the number of arm/hand injuries for each data collection year (1988-89 to 2007-08). These calculations were also stratified by age groups (0-14 years, 15-24 years, 25-49 years, 50 years and older). Helmet use compliance was based on data from a report by Smith and Milthorpe [21], which is the best available data.

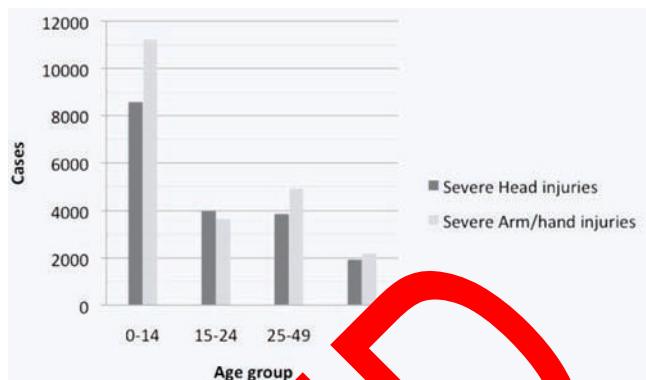
**Table 1. ICD10 codes corresponding to head and arm/hand injuries**

Place of injury	ICD10 code
Head injuries	S00-S09
Arm/hand injuries	S40-S49
	Injuries to the shoulder and upper arm
	S50-S59
	Injuries to the elbow and forearm
	S60-S69
	Injuries to the wrist and hand

## Results

From 1988-89 to 2007-08, there were 22,017 cases of cyclists being hospitalised due to injuries sustained to their hand or arm and 18,370 cases due to injuries sustained to their head. Cases aged less than 14 years of age were over-represented in the data with approximately 51% of severe arm/hand injuries and 47% of severe head injuries occurring in this age group (Figure 1).

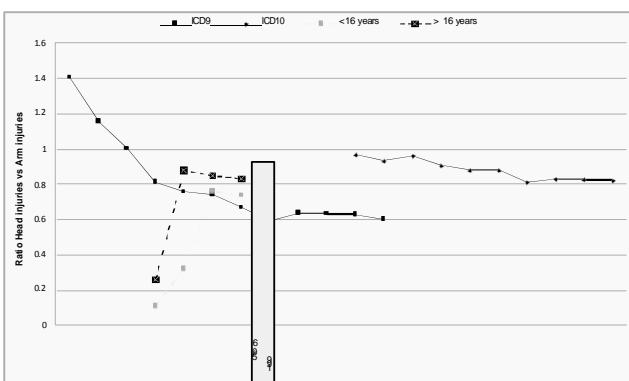
The total number of head injuries declined from 702 in 1988-89 to 581 in 1999-2000, with the most marked decline in the '0-14 years' age group (Table 2). However, the majority of the decline occurred prior to the helmet legislation and before helmet use compliance increased. Figure 2 shows the ratio of head to arm injuries declining steeply from 1988-89 to 1990-91 (mandatory helmet legislation was enacted for adults on 1 January 1991) and then continuing to decline slightly before leveling out. This pattern for the ratio of head to arm injuries is evident for all age groups (Table 3).



**Figure 1. Number of hospital separations for cyclists by age group and selected location of principal injury, NSW 1997-98 to 2007-08**

For children aged 5-14 years, the greatest decline in the ratio of head to arm injuries was in the two fiscal years 1990-91 and 1991-92, demonstrating the strongest temporal association with the introduction of the legislation, although there had been similar decreases before the legislation and the decline flattens out after 1994. For 15-24 year olds, there was a strong decline in the ratio of head to arm injuries from fiscal year 1991-92 to 1992-93 before increasing again and then leveling out. For both the '25-49 years' and '50 years and older' age groups, the greatest declines were before the 1991-92 fiscal year, with ratios leveling out soon after.

There was a lag between the introduction of the helmet legislation and compliance with the law, such that actual wearing of helmets by a majority of the population took 6 to 12 months. Compliance for all ages increased from approximately 18% to 78% three years after the legislation (see Figure 2) [21]. Because of the delayed (by six months) introduction for children, helmet wearing by children under 16 years is correspondingly later.



\*Mandatory helmetwearing legislation introduced for adults 1 January 1991

**Figure 2. Ratio of head to arm injuries from 1988-89 to 2007-08 for all ages, plus self-reported helmet use for those younger than 16 years, and over.**

**Table 2. Cases of head and arm injuries for hospitalised cycling-related injuries by age group**

Year	Ages 0-14				Ages 15-24				Ages 25-49				Ages 50+				All ages			
	Head		Arm		Head		Arm		Head		Arm		Head		Arm		Head		Arm	
	ICD9	ICD10	ICD9	ICD10	ICD9	ICD10	ICD9	ICD10	ICD9	ICD10	ICD9	ICD10	ICD9	ICD10	ICD9	ICD10	ICD9	ICD10	ICD9	ICD10
1988-89	421		334		134		92		87		59		20		14		702		499	
1989-90	423		409		193		128		108		69		23		26		770		666	
1990-91	356		338		152		98		94		73		27		32		640		638	
1991-92	291		397		133		92		85		92		18		28		509		627	
1992-93	310		446		124		128		98		130		16		31		579		765	
1993-94	315		476		126		112		89		103		21		40		513		692	
1994-95	311		521		112		117		88		135		26		31		505		756	
1995-96	330		617		128		162		91		133		13		43		532		904	
1996-97	373		595		143		175		81		139		18		50		581		913	
1997-98	386		640		146		155		96		178		24		41		618		979	
1998-99	288	554	484	587	120	223	146	209	93	224	147	243	20	157	38	173	511	1170	812	1212
1999-2000	339	620	567	712	137	281	166	234	97	269	185	315	18	147	52	157	581	1323	966	1421
2000-01	574		612		272		251		274		299		142		157		1293		1341	
2001-02	466		615		256		226		321		379		185		169		1321		1462	
2002-03	544		675		230		241		310		379		181		177		1355		1540	
2003-04	479		678		248		227		317		403		96		171		1519		1731	
2004-05	480		753		256		255		279		387		187		187		1514		1863	
2005-06	496		641		291		271		329		493		198		233		1624		1956	
2006-07	445		657		294		266		331		475		224		232		1619		1955	
2007-08	403		526		248		219		301		438		208		216		1443		1754	

Table 3. Ratio of head to arm injuries for hospitalised cycling-related injuries by age group

Year	Ages 0-14		Ages 15-24		Ages 25-49		Ages 50+		All ages	
	ICD9	ICD10	ICD9	ICD10	ICD9	ICD10	ICD9	ICD10	ICD9	ICD10
1988-89	1.260479		1.456522		1.474576		1.428571		1.406814	
1989-90	1.03423		1.507813		1.565217		0.884615		1.156156	
1990-91	1.053254		1.55102		1.287671		0.84375		1.003135	
1991-92	0.732997		1.445652		0.923913		0.642857		0.811802	
1992-93	0.695067		0.96875		0.753846		0.516129		0.756863	
1993-94	0.661765		1.125		0.864078		0.525		0.741329	
1994-95	0.596929		0.957265		0.651852		0.83871		0.667989	
1995-96	0.534846		0.790123		0.684211		0.302326		0.588496	
1996-97	0.626891		0.817143		0.582734		0.36		0.636364	
1997-98	0.603125		0.941935		0.539326		0.585366		0.631256	
1998-99	0.595041	0.943782	0.821918	1.066986	0.632653	0.921811	0.526316	0.907514	0.62931	0.965347
1999-2000	0.597884	0.870787	0.825301	1.200855	0.524324	0.853968	0.346154	0.936306	0.601449	0.931034
2000-01		0.937908		1.083665		0.916388		0.904459		0.964206
2001-02		0.757724		1.132743		0.846966		1.094675		0.903557
2002-03		0.805926		0.954357		0.817942		1.022599		0.87987
2003-04		0.70649		1.092511		0.7866		0.561404		0.877527
2004-05		0.63745		1.003922		0.72093		1		0.812668
2005-06		0.773791		1.073801		0.667343		0.849785		0.830266
2006-07		0.677321		1.105263		0.696842		0.965517		0.828133
2007-08		0.76616		1.13242		0.687215		0.962963		0.822691

## Discussion

It is apparent from the results that the ratio of head to arm injuries was already declining in NSW before the introduction of mandatory helmet legislation, and certainly before the self-reported level of helmet use increased. This is consistent with other data, indicating a general decline in motor vehicle related fatalities and morbidity in NSW from 1950 to the present, but in particular between 1980 and 1990 [6]. A similar pattern of decline is evident for pedal cycle fatalities, with a steep drop in cycling deaths from 98 in 1989 to 41 in 1992, corresponding with a similar drop in head injuries [22].

It is most likely that a series of changes in road safety and conditions before 1991 contributed to a generally safer road environment, which benefited people cycling as well as other road users. For example, on 17 December 1982, New South Wales introduced random breath testing, with an immediate decline in road deaths that soon stabilised at a rate approximately 22 per cent lower than the average for the previous six years [23]. The introduction of intensive road safety advertising in 1989 and the introduction of speed camera programs in 1990, plus the implementation of national road safety strategies (e.g., STAYSAFE Committee), all contributed to marked reductions in traffic-related mortality and morbidity through the 1980s and early 1990s [24].

The analysis presented here explored the relationship between mandatory helmet legislation and head injuries among cyclists by removing problems due to a lack of the number of people cycling as a denominator. By using hand/arm injuries by cyclists as a control, cyclists are compared with cyclists and any change in the ratio of the head to arm injuries should be the result of a change in practice, such as helmet wearing.

Two other previous papers looking at the impact of helmet legislation reported on pedestrian deaths and head injuries as a comparison with cyclists before and after 1991. Robinson found a decline in deaths and serious head injuries among pedestrians paralleled the decline in these injuries among cyclists between 1988 and 1992 [15]. Between 1988 and 1994, the decline in deaths from head injuries among pedestrians was 8% greater than the decline in deaths from head injuries among cyclists [25]. Clearly pedestrians are not affected by helmet legislation, yet the reduction in head injuries among pedestrians supports the idea that factors other than helmets may be responsible for generally safer road conditions.

New Zealand introduced mandatory helmet legislation on 1 January 1994. There was a dramatic increase in helmet use and a 51% drop in the number of trips by bicycle between 1989-90 and 2003 to 2006 [26]. An analysis of changes in head injury rates noted a gradual decline over time, but no marked improvement associated with increased helmet use compliance [27].

Robinson criticised the results, noting that, similar to the NSW data, the ratio of head injuries to limb injuries among cyclists had begun falling well before New Zealand's helmet law went into effect [28]. Between 1993 and 1994, the law dramatically

increased helmet use from 43 per cent to 93 per cent of cyclists, but head injuries continued declining at the same rate as before [28]. An examination of road user fatalities in New Zealand found that cyclist fatalities did not fall at any greater rate than for other road users after law enforcement in 1994, even with fewer people cycling [29].

Four provinces in Canada have helmet legislation for children aged less than 18 years, with one analysis of head injury rates before and after the legislation demonstrating reductions in head injury rates [30]. However, in two of the provinces (Ontario and British Columbia) representing 89% of the total data set, most of the falls in head injuries again took place before the laws came into effect [31]. In British Columbia head injury increased in the year following the law and then declined at a rate not significantly different to provinces with no law. In Ontario post-law, the decline in head injuries was also similar to provinces with no law [31]. This suggests that changes in the road environment or other factors, rather than helmet legislation, may have been responsible for the changes.

Sweden is the only other country to introduce mandatory helmet legislation, in their case for children under 15 years of age in 1991. Data from the Swedish National Road and Transport Research Institute show clearly that helmet use increased since 1991, and over the same period the number of children cycling declined [32]. Israel and Mexico City have introduced helmet legislation, but subsequently repealed it [33], in part because of the difficulties it created for introducing free bicycle loan schemes.

With approximately half of the head injuries reported in the present study being among young people, this group warrants further attention for cycling safety. Although general improvements to the road environment and cycling conditions will benefit children, their relatively lower levels of cycling skills and road awareness may mean that mandatory helmet wearing should continue for children, provided it does not lead to reduced numbers of children cycling. The case for continued mandatory helmet wearing for adults is questionable.

## Limitations

The transition from ICD9 to ICD10 codes has meant some inconsistencies in tracking over time. We mapped ICD10 codes onto ICD9 codes, although the mapping is not perfect. The hospitalisations used in this analysis represent the most severe cases, and other important cycling-related injuries such as unreported injuries or Emergency Department presentations (although less severe) are excluded. Also, analysis of population-level hospital separation data, which is collected for other purposes, does not allow the attribution of any direct causal effect or non-effect of the introduction of mandatory helmet use legislation on injury rates. Other possible confounders may explain apparent relationships. However, from a practical and policy perspective, the introduction of mandatory helmet legislation does not appear to be temporally associated with a substantial drop in head injuries among cyclists.

## Conclusion

The main conclusion of this examination of the ratio of head to arm injuries over time is that there was a marked decline in head injuries among pedal cyclists before the introduction of mandatory helmet legislation and behavioural compliance, most likely a result of a range of other improvements to road safety. Helmet use is likely to prevent some head injury, particularly for younger age groups, and may also reduce severity of injury. However, the mandatory bicycle helmet legislation appears not to be the main factor for the observed reduction in head injuries among pedal cyclists at a population level over time.

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# Cyclist visibility at night: Perceptions of visibility do not necessarily match reality

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## Abstract

Visibility limitations make cycling at night particularly dangerous. We previously reported cyclists' perceptions of their own visibility at night and identified clothing configurations that made them feel visible. In this study we sought to determine whether these self-perceptions reflect actual visibility when wearing these clothing configurations. In a closed-road driving environment, cyclists wore black clothing, a fluorescent vest, a reflective vest, or a reflective vest plus ankle and knee reflectors. Drivers recognised more cyclists wearing the reflective vest plus reflectors (90%) than the reflective vest alone (50%), fluorescent vest (15%) or black clothing (2%). Older drivers recognised the cyclists less often than younger drivers (51% vs 27%). The findings suggest that reflective ankle and knee markings are particularly valuable at night, while fluorescent clothing is not. Cyclists wearing fluorescent clothing may be at particular risk if they incorrectly believe themselves to be conspicuous to drivers at night.

## Keywords

Night visibility, Cyclists, Reflective clothing, Age

## Introduction

Cyclists are considered to be among the most vulnerable of all road users. They have among the largest proportion of self-reported near-miss crashes, significantly higher than that of motorists and comparable to that of pedestrians [1]. The injury consequences of a crash are also more severe for cyclists, where the probability of a cyclist being seriously injured following involvement in a crash was found to be almost 27% in Australian data collected over a four-year period [2]. The vulnerability of cyclists was further highlighted by Sonkin et al. [3], who reported that while child pedestrian fatality rates per 10 million miles fell from 1.08 to 0.27 (75%) during the period 1985 to 2003, child cyclist fatality rates only decreased from 0.84 to 0.55 (35%) per 10 million miles travelled.

Night-time cycling has been shown to be more dangerous than cycling in daylight, with 40% of cyclist fatalities occurring at night despite much lower exposure rates than in the daytime [4]. Rodgers [5] notes that while only 12% of cyclists reported that they rode after dark, 35% of cyclist deaths occur outside of daylight hours. The role of visibility in contributing to fatal accidents was examined further by Owens and Sivak [6], who

found that 78.8% of all fatal collisions involving vulnerable road users (cyclists or pedestrians) occurred during low-light conditions. When visibility was degraded further by poor atmospheric conditions, such as rain or fog, 92.3% of all fatal accidents involving a vulnerable road user occurred in low-light conditions [6]. A high proportion of cyclist fatalities have been reported to be related to problems with frontal rather than rear conspicuity [7], and motorists involved in night-time collisions with cyclists commonly report that they did not see the cyclist until it was too late to avoid a collision [8, 9].

The use of static or flashing front and rear bicycle lights is one widely adopted approach for improving cyclist visibility and is now a legal requirement when cycling on roads at night in many countries, including Australia. Another relatively inexpensive and practical approach to improving the conspicuity of cyclists is the use of high-visibility clothing.

In a previously published survey of 1460 participants (622 drivers and 838 cyclists), Wood et al. [10] explored the beliefs and attitudes of cyclists and drivers regarding cyclist visibility and safety, and cyclists' use of different clothing configurations, with a particular focus on improving visibility under reduced illumination conditions, including dawn, dusk and night-time. In that study we found that cyclists believe they are more visible (and that they are visible at longer distances) than did drivers under the same circumstances.

This was early evidence that, like pedestrians [11], cyclists may overestimate their own visibility in low light conditions. The survey also revealed that although cyclists endorsed the use of high-visibility clothing and aids, particularly in low-light conditions, relatively few cyclists reported wearing selected high-visibility clothing on a regular basis. Cyclists as a group may thus underestimate the importance of attracting other road users' attention when visibility is limited, such as under night-time conditions.

In the study described above [10], cyclists also rated wearing a reflective vest as being the most effective means of improving visibility, over and above the use of reflective strips worn on the moveable joints. This is relevant because empirical research on the night-time conspicuity of pedestrians has repeatedly revealed the opposite: that reflective strips on the major moveable joints are highly effective in improving pedestrian conspicuity, presumably due to humans' high perceptual sensitivity to distinctively human patterns of joint movement ('biological motion' or 'biomotion') [12].

Numerous studies have demonstrated that drivers are able to recognise the presence of pedestrians more often and at much longer distances when they are wearing reflective strips in a biomotion configuration, than when they wear a reflective vest [13-15]. It is thought that reflective vests are less useful because they limit the placement of the reflective material to the torso, which presents much less motion information to approaching drivers. Although the patterns of movement involved in cycling are inherently different from those associated with being a pedestrian, highlighting a cyclist's movements (by placing reflective markings on the cyclist's ankles and knees) might be an effective low-cost approach to enhancing cyclist conspicuity.

In our survey [10] we also found that cyclists may overestimate the usefulness of some visibility aids – for example, fluorescent clothing – at night. Fluorescent clothing acts by converting the wavelength of ultra-violet (UV) light (present in sunlight) to longer visible wavelengths, which leads to an overall increase in reflected visible light under daytime conditions. However, streetlights and vehicle headlights do not provide substantial amounts of UV; thus, fluorescent materials are not a particularly valuable conspicuity aid during typical night-time conditions. Interestingly, the majority of the cyclists and drivers in our survey considered fluorescent bicycle clothing to be more visible at night than white clothing. Therefore, road users may also be inadequately informed regarding the limitations of certain visibility aids. The failure of road users to understand such issues could be critical.

In the current study we evaluated the benefits of a range of visibility aids for cyclists under real world night driving conditions. These data are important, as without objective evidence demonstrating the effect of improving visibility on drivers' perceptions and reactions to cyclists on the road, it is not possible to inform cyclists or other road users with regard to their benefits, or indeed possible limitations.

We included both young and older drivers in this study in order to explore the extent to which driver age impacts on night-time cyclist visibility, given that previous studies have shown that pedestrian visibility at night is significantly impaired with increasing age [13, 14]. We compared the on-road data collected here with the perceptions of cyclists' own visibility that we had gathered in our previous survey-based study, which determined how well cyclists' *perceptions* of visibility aids aligns with the *actual* benefits of visibility aids [10].

## Methods

In this study volunteer participants drove around a closed road driving circuit at night and indicated when they recognised the presence of a cyclist wearing a range of different clothing configurations.

## Participants

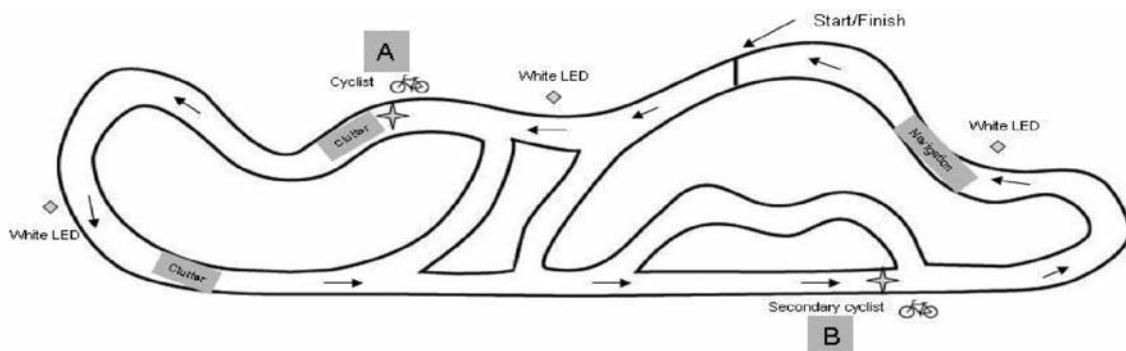
Participants included 12 young ( $M = 25.3$  years, range 18-35) and 12 older ( $M = 72.5$  years, range 66-80) visually normal individuals who had a current driver's licence and were regular drivers, with a visual acuity of 6/9 (20/30) or better. The study was conducted in accordance with the requirements of the Queensland University of Technology Human Research Ethics Committee.

## Closed-road test circuit and experimental vehicle

All driving was conducted under night-time conditions and was assessed on a 1.8km closed-road circuit [13, 14]. The circuit, which is representative of a rural road, consisted of a two- to three-lane bitumen road and included hills, bends, curves, lengthy straight sections, and standard road signs and lane markings. There was no additional ambient lighting on the circuit, and experimental sessions were only conducted on nights when there was no rain and the road surface was dry.

Two cyclists were positioned at different locations around the circuit, and pedalled in place on a resistance trainer so as to ensure naturalistic cyclist motion, while maintaining a consistent location that is critical for purposes of experimental control (Figure 1). Each cyclist was equipped with a two-way radio, as was the experimenter in the test vehicle. This allowed all communications regarding participant clothing to be conducted between laps and outside of the vehicle, so that the participants could not hear the conversations.

The data presented in this paper relate to the test cyclist positioned at point 'A' at the top left of Figure 1. In order to isolate the effects of clothing on cyclist visibility, the bicycle did not have front or rear lights. We have previously observed that a significant proportion of cyclists do not always use their lights under low-light conditions, and so this reflects a reality of night driving [10].



**Figure 1.** Schematic map of the closed-road circuit showing the location of the two cyclists and the three clutter zones. The test vehicle's direction of travel is indicated by arrows. The position of the glare lights are indicated by stars.

To simulate the effects of other vehicles being present, two pairs of battery-powered headlights were placed along the circuit, in close proximity to the test cyclist. The glare lights were positioned 5.4m in front of and 5.1m to the left of the test cyclist (when viewed from the perspective of an approaching driver). To the driver, these headlights approximated an oncoming vehicle's headlights and the glare from them added a degree of visual challenge. The test cyclist was positioned in the outermost oncoming lane (as seen from the participant's point of view) and was a minimum of two lanes removed from the test vehicle. The test cyclist was also surrounded by clutter provided by an array of reflective cones and posts.

To provide an additional degree of visual complexity and also to act as distractors, three additional clutter zones were set up along the circuit. Two of the clutter zones consisted of small- and medium-sized retro-reflective traffic cones, large retro-reflective posts and flashing amber lights. The third zone consisted solely of three pairs of large retro-reflective traffic cones and was used as a 'navigation zone' – where the driver was required to guide the test vehicle through the zone without hitting any cones. This was done to increase driver workload.

White flashing LEDs were positioned at three locations around the circuit, which served to simulate an oncoming bicycle and also to reduce the expectancy of the drivers. The LEDs were positioned on the right-hand shoulder of the road on black posts at a height approximating the front light of a bicycle.

The direction that the test cyclist faced was also varied between laps to simulate the two most common crash configurations reported by cyclists in our previous paper [10], where 38% reported a crash in which the motorist collided with a cyclist turning across their path when they were both heading in the same direction, and 19% reported being sideswiped. For half of the laps the cyclist faced in the same direction as the driver, and for half the laps the cyclist was positioned side-on to the driver (see Figure 2), as if they were about to enter the traffic from a street at 90 degrees to the driver's direction of travel.



**Figure 2. Photograph of the section of the road circuit where Cyclist A was positioned**

## Clothing conditions

For each lap, the test cyclist wore one of four clothing outfits: (1) a black tracksuit, (2) a black tracksuit with a fluorescent yellow cycling vest with no retro-reflective materials present, (3) a black tracksuit plus a fluorescent yellow cycling vest that included silver retro-reflective markings (Netti Litehook®) on the shoulders, front and rear of the torso, or (4) the same black tracksuit and retro-reflective vest with the addition of 50mm-wide silver retro-reflective strips (3M Scotchlite® 8910 silver fabric) positioned on the cyclist's ankles and knees.

A second cyclist was present on all laps at location B (see Figure 1). This reduced the participants' ability to associate a cyclist with a particular location on the circuit. The second cyclist wore the same range of clothing configurations as the test cyclist in an independently determined random order (minus the fluorescent vest).

## Procedures

Participants drove around the circuit in a right-hand drive sedan fitted with two digital video cameras mounted on the roof of the vehicle [16]. The system recorded two overlapping images of the road scene and was linked to a LED marking system, which recorded the moment the participant pressed a large luminous dash-mounted touch pad to indicate recognition.

Participants were given a practice lap in order to familiarise themselves with the car, the road circuit and the tasks required of them. The practice lap was followed by 10 data collection laps. These comprised the eight combinations of cyclist clothing and bicycle direction presented in a random order for each participant, plus two laps where the test cyclist was absent, which was held constant between participants.

Participants were instructed to follow the specified route, to drive at a comfortable speed and to press the touchpad whenever they recognised that a cyclist was present in the road scene ahead. Participants were instructed to read aloud all road signs encountered so as to increase driver workload (these data were not recorded). To quantify the participants' responses to the cyclist we recorded whether the participant pressed the response button at any point along their approach to the cyclist. Thus, we could track the percentage of trials in which the participants correctly identified the presence of the test cyclist.

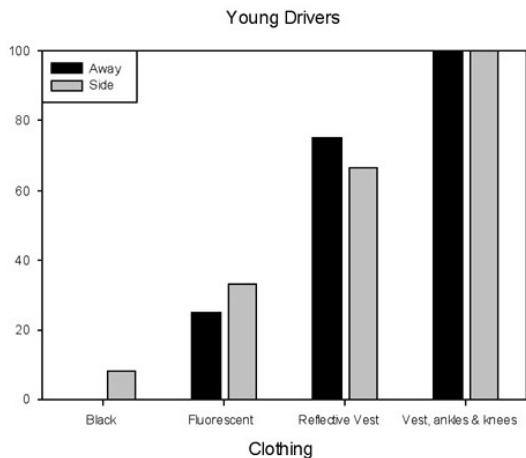
## Results

An independent samples t-test was conducted on the proportion of cyclists recognised by each participant, according to the age group of the participants. There were four false sightings of pedestrians over the total of 240 laps, but this number was too small to be usable in the analysis.

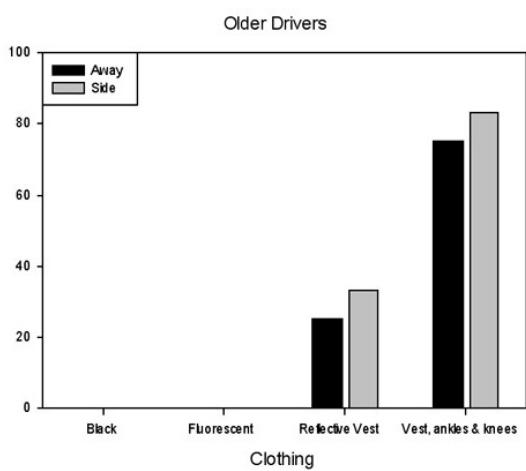
Overall, younger drivers identified nearly twice the number of cyclists as did older drivers; on average, younger drivers identified just over half of the cyclists (51%), whereas older drivers identified just over a quarter (27%). This age effect was

significant,  $t(22) = 4.12$ ,  $p < .001$ . As can be seen in Figure 3, older drivers did not detect any of the cyclists wearing black or fluorescent clothing, and less than half of the cyclists wearing reflective vests. Younger drivers performed much better; however, they detected less than half of the cyclists wearing black or fluorescent clothing.

A



B



**Figure 3. Percentage of cyclists recognised as a function of clothing and cyclist direction for the young (A) and older (B) drivers**

A repeated measures t-test was conducted on the proportion of cyclists recognised by each participant according to whether the cyclists were entering the roadway as if from a side road or were pedalling in the same direction as the driver, and found no significant differences  $t(22) = .81$ ,  $p = .427$ . Data were thus combined across the direction conditions, to enable a two-way analysis of variance between clothing and age in terms of the number of cyclists correctly identified.

The analysis revealed a large overall effect of clothing,  $F(3,66) = 45.7$ ,  $p < .001$ . Overall, drivers identified the largest number of cyclists wearing the vest plus the ankle and knee reflectors (90% correctly recognised), followed by the reflective vest alone (50%), the fluorescent clothing (15%), and lastly black clothing (2%). All pair-wise differences were significant, with the

exception of black and fluorescent clothing, which were not significantly different from one another.

There was no significant interaction between age and clothing, indicating that the effects of clothing were similar for the two age groups,  $F(3,66) = 1.83$ ,  $p = .151$ . While older drivers were less likely than young drivers to identify the cyclists, the degree to which they were less successful than young drivers did not vary according to clothing configuration.

## Discussion

In this field study we sought to determine how the ability of drivers of different ages to recognise the presence of cyclists at night-time is influenced by the cyclist's clothing. The data demonstrate that cyclist clothing and driver age both significantly affect the ability of drivers to recognise cyclists under real world night-time driving conditions. Collectively these results are important, particularly when considered in the context of our previously collected data regarding cyclists' perceptions of their own visibility and how often they wear such visibility aids.

There was a strong effect of clothing on the percentage of cyclists who were recognised by drivers. Adding ankle and knee markings to a typical reflective cycling vest provides a powerful enhancement of the cyclist's conspicuity. This manipulation increased the percentage of drivers who recognised that a cyclist was present from 50% to 90% overall, with 100% of cyclists being recognised by the younger cohort of drivers.

Even though this configuration did not use a 'full' biological motion configuration, the effect was just as robust as those demonstrated in prior studies for pedestrian visibility [13-15]. That the cyclist only wore the reflectors on the ankles and knees and yet was still easily recognised suggests that 'full' biological motion (i.e., placing reflectors on all major moveable joints) may not be necessary for the successful recognition of cyclists, and that a convenient subset – marking just the ankles and knees – may be sufficient. This hypothesis will be further explored in our future studies.

Recognition of the cyclist wearing the reflective vest without the ankle and knee markings (50%) was better than for the cyclist wearing either the fluorescent (15%) or black clothing (2%), but for older drivers, recognition levels for the vest were as low as 30%. This may be a surprise to the many cyclists who rely on reflective vests as a visibility aid at night. It may not, however, be unexpected to researchers, who have previously demonstrated that pedestrians also have a strong tendency to overestimate their own visibility at night and to underestimate the conspicuity benefits provided by biological motion [11].

The relatively low conspicuity levels of the cyclists when wearing the reflective vest alone is likely to be attributable to the lack of perceptible torso motion signifying the presence of a cyclist. Importantly, in our survey [10], cyclists ranked reflective vests as being most visible under reduced illumination

conditions. Thus, typical cyclists do not seem to appreciate that reflective vests may not maximise their conspicuity and that biological motion markers can increase their conspicuity. Added to this is the low level of use of visibility aids in general by cyclists at night, with only 35% of cyclists reporting that they wear reflective clothing either ‘often’ or ‘always’.

Our findings that the visibility benefits of fluorescent vests are small, that they do not offer a significant improvement on black clothing, and that older drivers fail to recognise cyclists wearing fluorescent clothing on any trials are important when considered in light of the results of our earlier survey [10]. In that study both cyclists and drivers rated the visibility benefits of fluorescent vests to be high even under night-time conditions; indeed, there was little difference in their ranking of the visibility benefits of the fluorescent clothing for either day or night-time conditions.

However, fluorescent materials have little visibility benefit at night, as they are activated only by UV radiation, which is lacking in headlights and streetlights. Cyclists appear to assume incorrectly that the visibility advantage of fluorescent materials is equivalent irrespective of lighting. Thus, cyclists who habitually wear fluorescent – as opposed to reflective – materials may considerably overestimate their visibility at night. This may result in cyclists unintentionally placing themselves at elevated risk. Future research should explore the interaction between bicycle lights and clothing to ascertain whether there are differential effects on cyclist visibility at night.

Overall, the older drivers recognised cyclists significantly less often than did younger drivers. While the younger drivers saw the cyclists 51% of the time, older drivers identified them only 27% of the time and never identified them wearing black or fluorescent clothing. The reduction in the ability of older drivers to recognise the cyclists is likely to be due partly to changes in visual function, especially age-related changes in visual acuity and contrast sensitivity (ability to see faint images), which may be exacerbated under low luminance conditions [17].

Importantly, when the cyclists were wearing the vest with reflectors on the ankles and knees, the older drivers recognised them (80%) almost as often as did the younger drivers (100%). The finding that cyclists are rarely seen by older drivers when they are not wearing reflective clothing at night is important, given the growing numbers of older drivers on our road systems and the fact that many drive at night-time.

Collectively, the findings of this study provide important preliminary data to suggest that cyclist visibility in low light is strongly influenced by the clothing worn by the cyclist, and highlight the importance of education among the general population with regard to the utility of high-visibility clothing. The data also underscore the fact that even alerted drivers commonly fail to recognise the presence of cyclists, dependent on the clothing configurations worn. These data also provide evidence to support our previous findings with regard to

misunderstandings that cyclists have with regard to their own visibility at night and suggest that cyclists may need to be better informed with regard to the limits, as well as the benefits, of specific visibility aids.

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# The role of traffic violations in police-reported bicycle crashes in Queensland

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## Abstract

Media articles have promoted the view that cyclists are risk-takers who disregard traffic regulations, but little is known about the contribution of cyclist risk-taking behaviours to crashes. This study examines the role of traffic violations in the 6774 police-reported bicycle crashes in Queensland between January 2000 and December 2008. Of the 6328 crashes involving bicycles and motor vehicles, cyclists were deemed to be at fault in 44.4% of the incidents. When motorists were determined to be at-fault, 'failure to yield' violations accounted for three of the four most reported contributing factors. In crashes where the cyclist was at fault, attention and inexperience were the most frequent contributing factors. There were 67 collisions between bicycles and pedestrians, with the cyclist at fault in 65.7%. During the data period, 302 single-bicycle crashes were reported. The most frequent contributing factors were avoidance actions to miss another road user and inattention or negligence.

## Keywords

Bicycle crashes, Traffic violations

## Introduction

Cycling provides substantial health, environmental and economic benefits [1-3]. Despite the benefits associated with cycling, many cyclists are injured in road crashes, and significant conflict can develop between bicyclists and other road users. This is one of the major deterrents to cycling participation. Cyclists comprised 14.6% of all road users admitted to hospital as a result of road vehicle traffic crashes in Australia in 2006-07 [4], an increase from 12.8% in 2003-04 [5].

The negative opinions drivers have of cyclists are frequently reported in the popular media, and responses to news reports on public forums highlight the gulf between cyclists' and drivers' opinions. Some drivers believe that they are the victims of cyclists and that cyclists are putting themselves and other road users at risk [6]. Most drivers believe cyclists are inconvenient, with approximately 20% of drivers annoyed by cyclists because they impede drivers [7]. While UK research found that drivers believe cyclists should not be allowed on public roads due to the fact that they pose a risk to themselves and others [7], only 43% of the Australian drivers surveyed believed that cyclists should not ride on the same roads as cars [8]. Australian research demonstrates that many drivers (63%) believe that cyclists have no respect for road rules [8]. This

supports research which found that the primary reason drivers had a negative perception of cyclists was cyclists' perceived failure to adhere to road rules [7].

However, there has been little quantitative research into the level of adherence to road rules by cyclists in traffic situations. Some observational research into cyclist behaviour in general traffic situations has been conducted. Research from the US indicates that bicyclists who wear helmets are significantly more likely to use legal hand signals to indicate turns and come to a complete stop at an intersection, compared with non-helmeted riders [9]. It is difficult to draw conclusions from this research in the Australian context as helmets are not mandatory in US jurisdictions.

Compliance with traffic signals has been examined in the Australian context, with data collected at points along a prominent bicycle commuter route. Observations found that 7% of cyclists disregarded red traffic lights and proceeded through the intersection, and this behaviour was more frequent during the afternoon peak [10].

Crash analysis has examined the role of traffic violations in bicycle crashes in international contexts, with a focus on collisions between bicycles and motor vehicles. Research into bicycle-motor vehicle collisions found that at least one traffic violation was involved in 50% of bicycle fatalities in the UK [11], although there was no indication of the unit at fault. Other research has demonstrated that failure to yield was the most frequent single crash type leading to bicycle-vehicle collisions, with the cyclists at fault in 35.9% of crashes [12]. While useful, this research does not provide information with respect to other crashes in which bicycles are involved.

Road user behaviour is commonly considered to be determined by several factors, including risk perception and sensation seeking [18]. Research has also shown that a willingness to commit traffic violations is linked with traffic incident involvement [19]. The majority of the research has focused on motor vehicle operators. This has shown that greater predilection for sensation seeking increases the likelihood of a vehicle operator committing a traffic violation [20], which is unrelated to age or kilometres travelled [21].

This research also demonstrated that there is a difference between committing driving violations and other driver errors (mistakes, inexperience and lack of attention) [20]. It is important to keep in mind that it is often difficult to distinguish between driver errors and traffic violations. Driver errors are frequently identified as driver conditions in Queensland crash data. In the case of failure to yield, it may be a result of either

factor, and it is possible that the consequence of one is exacerbated by the other [18].

There are several issues that make analysis of bicycling data difficult. Data regarding the distance travelled by bicyclists, or even the number of cyclists, is not currently available. It is also difficult to conduct accurate analysis of bicycle crashes or collisions, because bicycle crashes have the lowest reporting rate in official road statistics, with less than 10% of single vehicle bicycle crashes reported [22]. While it is recognised that bicycle injuries are under-reported in police statistics, crashes involving other road users are more likely to be included due to incidents usually occurring on roadways and being more serious in nature [23]. Because of these reporting issues, bicycle crashes are examined with respect to the recorded collision partner (single vehicle, motor vehicles, pedestrians and other bicyclists).

The primary focus of this paper is to investigate the role of traffic violations in bicycle crashes. The data examines the ‘at fault’ status and contributing factors, with a focus on traffic violations, in bicycle crashes reported to police in Queensland. In Queensland, the police have a strong focus on the ‘Fatal four’ – speeding, alcohol, fatigue and seat belts – to reduce road trauma. As seat belt usage is not an appropriate issue to examine for bicycles, helmet use will be examined instead. These will be examined, in addition to other traffic violations, for their relevance to bicycle crashes. Separate analyses are presented of crashes between motor vehicles and bicycles and of single bicycle crashes, given the expected high level of under-reporting of the latter.

## Methodology

All crashes involving a bicycle between January 2000 and December 2008 inclusive were extracted from the Queensland Crash Database. Bicycle crashes included single-unit (bicycle) crashes and multiple-unit crashes. Multiple-unit crashes included motor vehicles, animals, other objects and pedestrians. Motor vehicles included motorcycles, special purpose vehicles, articulated vehicles, road trains/B-doubles, trucks, car/station wagons, utility/panel vans a bus/coaches. Unit types that were not included in the motor vehicle category were towed device, railway rolling stock, wheeled recreational device and other (undefined units).

In Queensland, crashes on a public road that result in injury or property damage of greater than \$2500 or a vehicle being towed away are required to be reported to police. Contributing circumstances are included in the crash reports data extracted from the database. These circumstances are assigned by police to one of seven general categories: traffic violations, vehicle defects, lighting conditions, atmospheric conditions, road conditions, driver conditions and miscellaneous factors.

‘Inattention/negligence’ and ‘undue care and attention’ appear to be similar contributing factors; however, there are differences as determined by police from the statements of involved parties and witnesses [24]. ‘Undue care and attention’ is a violation that includes careless driving, listening to the radio and lack of concentration. ‘Inattention/ negligence’ is a driver condition,

not a violation, and includes being on the wrong side of the road and pedestrians not looking before crossing the road. Driver conditions include the following factors: fatigue, inattention, inexperience, medical conditions, age, distraction, taking avoiding action and miscellaneous driver conditions.

## Results

Between January 2000 and December 2008, 6774 crashes involving bicycles were recorded in the Queensland Crash Database. This does not include crashes occurring on private property and areas not considered part of the road reserve. The majority of cyclists involved in crashes were male (82.3%), and cyclists aged 12-16 or 30-49 accounted for approximately half of all cyclists (49.4%) in crashes (see Figure 1). Most crashes involving bicycles occurred between 6am and 9am and between 3pm and 6pm, and in clear atmospheric conditions (95.2%). Very few crashes occurred on arterial (0.1%) or subarterial roads (9.2%). This profile may reflect the riding patterns. Most crashes involving bicycles resulted in injuries requiring medical treatment (40.6%) or hospitalisation (34.8%) or minor injury (23.1%). There were very few fatal (0.9%) or non-injury crashes (0.5%).

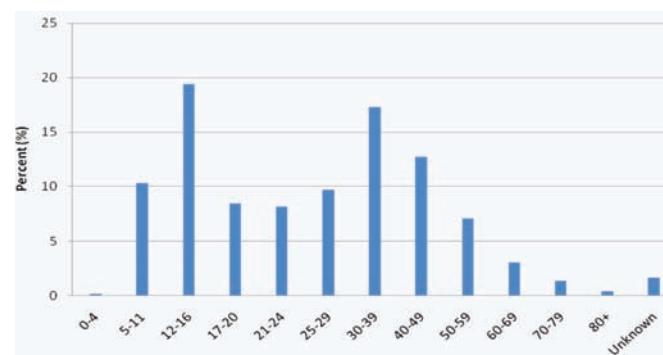


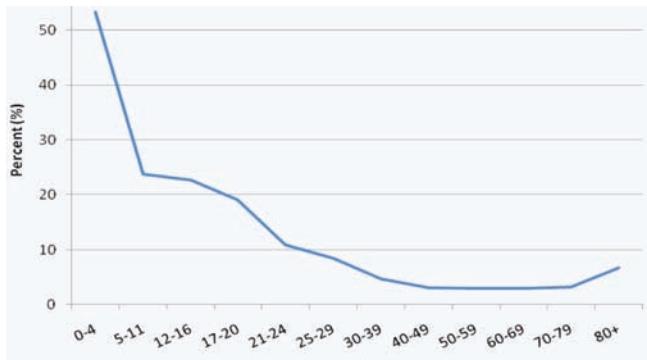
Figure 1. Age group of cyclists involved in police-reported crashes

The ‘Fatal four’ were reported to be involved in only 3.7% of all bicycle crashes. Speed was a factor in 1.1% of all reported bicycle crashes, with ‘excessive speed for circumstances’ accounting for 94.7% of contributing circumstances in speed-related crashes (primarily excessive bicycle speed).

Alcohol was involved in 2.4% of all reported bicycle crashes. Of the crashes where alcohol was involved, the majority were classed as ‘under the influence of liquor/drug’ (62.8% of alcohol involvement), rather than illegal blood alcohol content. Drivers and cyclists were equally likely to be under the influence of a substance.

Fatigue was nominated by police as contributing to 0.2% of reported bicycle crashes. Crashes identified as fatigue-related by the Queensland Transport Definition accounted for 15.4%, while ‘driver fatigue/fell asleep’ was recorded for 84.6% of fatigue crashes. Fatigue was primarily a factor attributed to drivers.

Helmets were not worn by cyclists in 12.0% of police-reported bicycle crashes. Helmet non-compliance was more likely for cyclists aged 20 years or younger (see Figure 2). While the percentage of cyclists aged 0-4 not wearing a helmet was 53.3%, this figure may not be reliable since it corresponds to only 15 of 7293 cyclists.



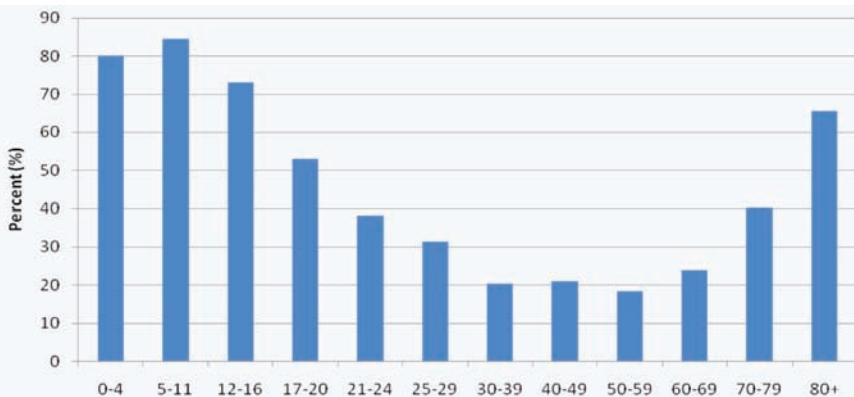
**Figure 2. Percentage of cyclists not wearing helmets in police-reported crashes, by age**

Further analysis of vehicle operator actions as contributing factors was examined in relation to the types of crashes: bicycle–motor vehicle crashes, single-vehicle crashes, bicycle–pedestrian crashes and multiple-bicycle crashes.

### Bicycle–motor vehicle crashes

From 1 January 2000 to 31 December 2008, there were 6328 crashes reported to police involving bicycles and motor vehicles, comprising 93.4% of police-reported bicycle crashes. The bicyclist was deemed the at-fault vehicle in 2809 instances (44.4%). Younger cyclists (16 years or younger) and elderly cyclists (80+ years) were more likely to be the at-fault unit, while cyclists aged 30-69 were at fault in less than 30% of bicycle–motor vehicle crashes (see Figure 3).

In general, injury severity was much greater for cyclists than motor vehicle occupants (operators or passenger) (see Table 1). Motorcyclists contributed approximately 60% of all serious injury (fatality and hospitalisation severity crashes) cases for motor vehicle occupants.

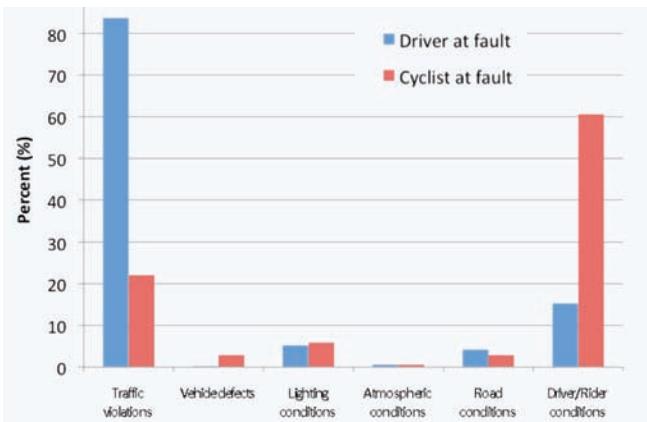


**Figure 3. Percentage of bicycle–motor vehicle crashes in which the cyclist was deemed at fault, by cyclist age**

**Table 1. Injury severity reported for bicycle–motor vehicle crashes, by road-user type**

Cyclist (n=6328)	Motor vehicle occupant (n=6328)
Fatality	0.9%
Hospitalisation	33.9%
Medical treatment	40.8%
Minor injury	23.9%
No injury reported	0.5%
	98.2%

The role of traffic violations as contributing factors changed according to the unit at fault (see Figure 4). When the motorist was at fault, traffic violations were recorded in 85.4% of crashes and driver conditions were recorded for 16.4% of crashes. When the cyclist was at fault, traffic violations were recorded in only 28.1% of bicycle–motor vehicle crashes.



**Figure 4. Contributing factors in police-reported bicycle–motor vehicle crashes, by unit deemed to be at fault**

The types of traffic violations also differed according to the unit deemed to be at fault (see Figure 5). When the driver was at fault, the most frequently recorded traffic violations were ‘undue care and attention’ (22.4%), ‘disobey give way sign’ (19.1%), ‘fail to give way’ (15.3%), ‘turn in the face of

oncoming traffic' (11.9%) and 'open car door causing danger' (5.9%). Only 'inexperience/lack of expertise' (5.9%) and 'age (lack of perception; power or concentration)' (3.7%) were frequently noted driver conditions when a driver was at fault. For crashes where the bicyclist was at fault, the most frequently recorded traffic violations were 'disobey traffic light' (6.4%), 'fail to keep left' (5.1%) and 'fail to give way' (4.7%). The contributing factors most likely to be indicated when a cyclist was the at-fault vehicle were 'inattention/negligence' (34.7%) or 'inexperience/lack of expertise' (26.5%).

While younger (16 years of age or younger) or older (60 years of age or older) cyclists are more likely to be at fault, contributing factors in these crashes are unlikely to be attributed to traffic violations. The most common contributing factors identified are age- or skill-related ('inexperience/lack of expertise' or 'age: lack of perception, power or concentration') and attention-related ('inattention/negligence').

There were similar rates of inattention cited for younger and older cyclist crashes (35.5% and 27.6%, respectively). Age-related factors were also cited in a similar proportion for younger and older cyclist crashes. 'Inexperience/lack of expertise' was nominated as a contributing factor in 47.6% for younger cyclist crashes (no older cyclist crashes). 'Age: lack of perception, power or concentration' was nominated as a contributing factor in 51.0% of older cyclist crashes.

### Bicycle-pedestrian crashes

There were 67 reported crashes involving bicycles and pedestrians. The majority of collisions occurred without traffic controls (79.1%), but 14.9% occurred at traffic lights and 3.0% occurred on pedestrian crossings. In general, the level of injury to the pedestrian was greater than to the cyclist (see Table 2).

The cyclist was at fault in 65.7% of all bicycle-pedestrian crashes, and traffic violations were recorded in 26.9% of these crashes (see Figure 6). The most common reported violation was 'disobey a traffic light' (recorded for 8 crashes, with the bicycle at fault in 6), followed by 'undue care and attention'

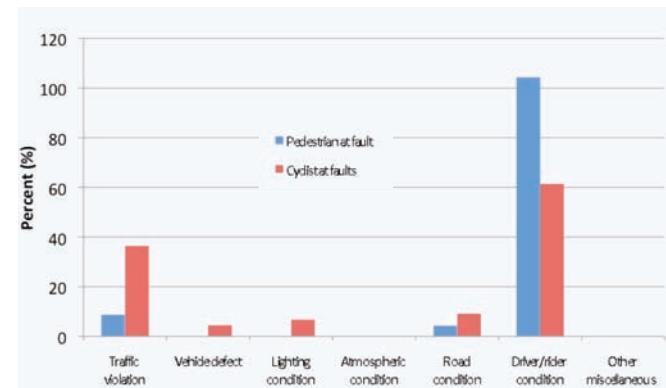
(6 occasions, all with the bicycle at fault). In crashes where the pedestrian was at fault, the most nominated contributing circumstances were 'inattention' and 'inexperience' (age factor).

**Table 2. Injury severity reported for bicycle-pedestrian crashes, by road user type**

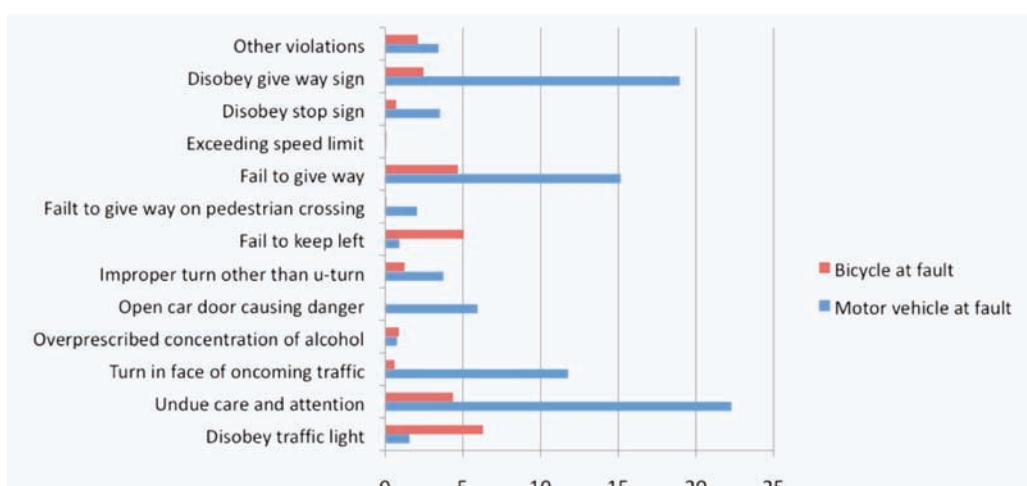
	Pedestrian (n=67)	Cyclist (n=67)
<b>Fatality</b>	3.0%	0.0%
<b>Hospitalisation</b>	43.3%	19.4%
<b>Medical treatment</b>	38.8%	13.4%
<b>Minor injury</b>	13.4%	17.9%
<b>No injury reported</b>	1.5%	49.3%

### Multiple-bicycle crashes

Only 38 multiple-bicycle crashes were reported between January 2000 and December 2008; only one resulted in a fatality (3%), and less than half resulted in hospitalisation (47%). Medical treatment was required in 29% of multiple-bicycle crashes, while 21% resulted in minor injury. There were no 'property damage only' crashes involving multiple bicycles.



**Figure 6. Contributing factors in police-reported bicycle-pedestrian crashes**



**Figure 5. Traffic violations in police-reported bicycle-motor vehicle collisions according to unit deemed to be at fault**

The most frequently reported contributing factor in multiple-bicycle crashes was inattention and negligence (29.0%). Vehicle defects, road conditions and lighting conditions combined were involved in 21.1% of all crashes, while traffic violations were involved in 26.3%. ‘Fail to keep left’ was the highest reported (four crashes), followed by ‘undue care and attention’ (three crashes). ‘Follow too closely’, ‘dangerous riding’, ‘over prescribed concentration of alcohol’ and ‘under the influence of alcohol’ were all involved in one crash.

### Single-bicycle crashes

In the period 1 January 2000 to 31 December 2008, there were 302 single-bicycle crashes reported to police. The majority involved male cyclists (84.4%), which was slightly higher than the total population of bicycle crashes. Off-carriageway crashes and out-of-control crashes were common (see Figure 7). Crashes defined as ‘Other’ within the Definition for Coding Accidents (DCA) group include all undefined actions (for all DCA groups), as well as ‘fell in/from vehicle’. The highest percentage of single-vehicle crashes resulted in hospitalisation (45%), followed by medical treatment required (39%), minor

injury (13%) and fatalities (3%). There were no ‘property damage only’ crashes.

Traffic violations were the fifth most common contributing factor associated with single-bicycle crashes behind rider conditions, road conditions, other miscellaneous factors and vehicle defects (see Figure 8). Only two traffic violations were recorded: ‘undue care and attention’ (5.3%) and ‘over prescribed concentration of alcohol’ (2.7%). However, ‘under the influence of liquor/drug’ (but not exceeding BAC limit) was recorded as a contributing factor in 6.6% of crashes. The most common contributing factors were ‘taking avoiding action to miss another road user’ (29.8%) and ‘inattention/negligence’ (15.9%).

### Discussion

The analyses reported here show that the motor vehicle was at fault in 65.6% of bicycle–motor vehicle crashes, with traffic violations recorded against 85.4% of these drivers. This contrasts sharply with the media articles and surveys portraying cyclists as risk-takers who disobey traffic regulations.

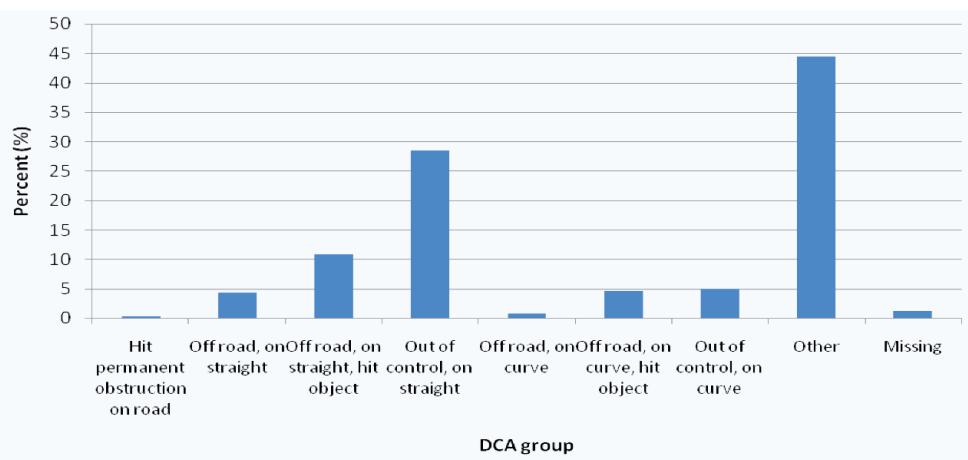


Figure 7. DCA (Definition for Coding Accidents) group for police-reported single-bicycle crashes

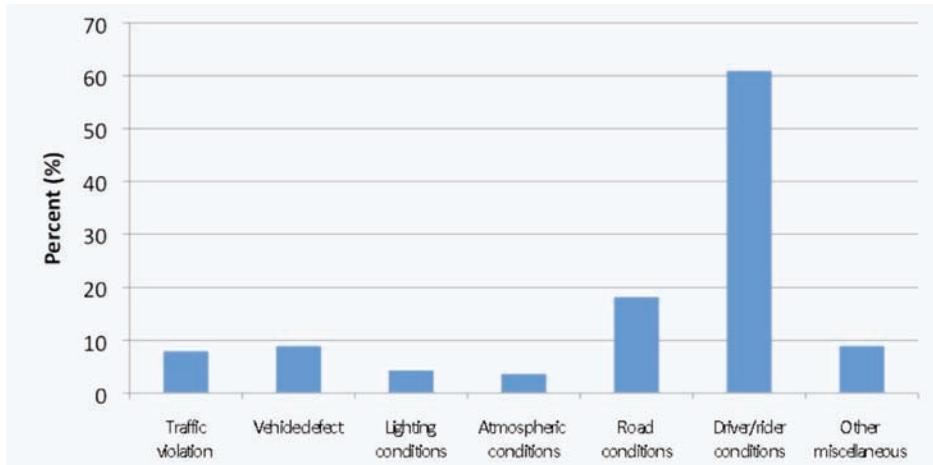


Figure 8. Contributing factors in police-reported single-bicycle crashes

The traffic violations committed by motor vehicle drivers largely related to various forms of failing to give way to cyclists: ‘disobey give way sign’, ‘fail to give way’, ‘turn in the face of oncoming traffic’. The crash data does not provide any information about whether these behaviours resulted from a failure to notice the cyclist, poor judgement of the speed of the cyclist or some more aggressive intent.

While the motor vehicle was at fault in the majority of bicycle–motor vehicle crashes, this was not the case for riders aged under 21 (particularly those under driver licensing age) and the very small number of riders aged 80 and over. Riders aged under 21 were also less likely to wear helmets. Given that 12-16 year olds comprised one of the largest groups of riders in bicycle crashes overall, it appears that the focus in addressing risk taking and violations by cyclists should perhaps focus on this group.

When cyclists were at fault in bicycle–motor vehicle crashes, the contributing factors were more often rider conditions (‘inattention/negligence’ or ‘inexperience/lack of expertise’) than traffic violations (28.1%). As well as being less common, the nature of the traffic violations by cyclists differed from those of drivers. ‘Disobey traffic light’ was the most common for cyclists, followed by ‘fail to keep left’, but these were rarely recorded for drivers. The former suggests some basis for the driver view that cyclists do not respect red lights (supported by [12]), and the latter may reflect cyclists’ unwillingness to ride to the far left of the road.

While the 67 bicycle-pedestrian crashes comprised only 1% of police-reported bicycle crashes, the bicycle rider was considered at fault in two-thirds of these crashes and the pedestrian was generally injured more severely than the cyclist. Cyclists received traffic violations for ‘disobey a red light’ and ‘undue care and attention’. It was unclear in the data whether the crash occurred on a footpath or road.

It is difficult to draw many conclusions about risk taking and disobeying traffic regulations in the single-bicycle crashes. It may be that riding too fast contributed to some of these crashes, but this was not reported by police and there were few traffic violations noted. In addition to the overall likely under-reporting of these crashes, it may be even less likely for cyclists to report single-vehicle crashes if they had been taking risks or disobeying traffic regulations.

This research has demonstrated the diverse ages of people cycling in Queensland. The results indicate that the majority of cyclists involved in crashes have reached an age where they can hold a drivers licence. However, a substantial portion (29.9%) are younger than 16, with 10.5% aged 11 or younger.

While no data is available in crash data on the licence status of cyclists involved in police-reported crashes, data from the Australian Bureau of Statistics estimates approximately 85% of Queensland residents who own a bicycle also hold a drivers licence [25]. This information indicates that the majority of

cyclists involved in crashes should be aware of the road rules. These results suggest that a lack of knowledge of road rules (for those cyclists younger than the legal driving age) and age-related cognitive abilities [26, 27], as well as risk-taking behaviours, are involved in bicycle crashes. All factors should be considered when developing interventions.

A major limitation of this study is the low reporting of bicycle crashes. Almost 90% of bicycle crashes go unreported, and are therefore not included in road crash statistics [28]. While injuries sustained in bicycle–motor vehicle crashes are more likely to result in serious injury and are therefore more likely to be reported, it is possible that the results for bicycle-pedestrian, multiple-bicycle and single-bicycle crashes are not truly representative of the number and actual circumstances of these crashes.

While driver perceptions are of cyclists being mavericks on the road, the crash data does not support this position. Driver opinions may be formed by anecdotal evidence, and further research could be conducted of road user behaviour to evaluate the general attitude towards the road rules by bicyclists. However, this research demonstrates that a cyclist is unlikely to commit a traffic violation that results in a single-vehicle crash or collision with another road user.

Policies have been proposed to increase the safety of cyclists as vulnerable road users. This has often been hindered by the divergent policies expressed by different departments within a single administrative unit. The Queensland Cycling Strategy and the Queensland Road Safety Strategy both have opposing views on the treatment of cyclists as road users [29]. Road safety interventions implemented as part of the Road Safety Strategy are designed to benefit vehicle occupants, while there are few benefits for cyclists and vulnerable road users in general.

This research demonstrates that to improve the safety of cyclists, several strategies could be beneficial. Younger bicycle riders could benefit from improved education regarding the road rules, and possibly improving skills when riding with traffic. A greater understanding of the impact of poor road surfaces on cycling safety may also reduce the risk of injury to cyclists. Rigorous enforcement of minor traffic offences for all road users, such as observing stop and give way signs, may result in greater improvements in cyclist safety in on-road situations. General education campaigns for all motorists emphasising the importance of focusing on the road and of obscure traffic regulations (for example, the requirement to open a car door safely) could also improve the safety of cyclists and other road users.

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## Painting a designated space: Cyclist and driver compliance at cycling infrastructure at intersections

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### Abstract

This study evaluated cyclist and driver compliance at cycling infrastructure at signalised intersections to determine the effectiveness of the infrastructure in creating a designated space for cyclists. A cross-sectional observational study was conducted during peak travel times at six sites in Melbourne in March 2009. Three types of infrastructure were observed: 1) bicycle storage box in front of left lane, 2) bicycle storage box in front of centre lane and 3) continuous green-painted bicycle lane. Two sites were observed for each infrastructure type, one morning and one early evening. A covert fixed position video

camera was used to film all road users, and the behaviour of cyclists and drivers who stopped at the intersection during the red light phase was coded. In total, 2670 cyclists and 1243 vehicles were observed. Compliance was highest at the continuous bicycle lane sites for cyclists (95.4%) and drivers (97.7%). At bicycle storage box sites, cyclists (60.4%) were more compliant than drivers (49.6%). The placement of bicycle storage boxes may contribute to lower rates of driver compliance and cyclists' perceptions of safety and subsequently cyclist compliance. Driver and cyclist education campaigns may increase compliance.

## Keywords

Cycling infrastructure, Driver compliance, Cyclist compliance, Bicycle storage box

## Introduction

On-road cycling infrastructure is designed to create designated spaces for cyclists. Recent studies suggest that treatments give drivers confidence about interacting with cyclists [1], cyclists prefer routes with cycling infrastructure [2-4] and report feeling safer [5,6]. However, for the infrastructure to be effective, drivers and cyclists need to be compliant, and there has been little research into how cyclists and drivers use these spaces and whether the infrastructure creates a clear space for cyclists on the road.

The number of people cycling in Australia is increasing [7] and so too is the introduction of cycling infrastructure. During the last decade in metropolitan Melbourne, for example, there has been a substantial increase in the installation of cycling facilities in an effort to improve the overall safety of cyclists, increase their visibility and legitimacy, and improve traffic flow [8]. The principal bicycle network currently has 1200km of completed on-road and off-road cycling routes [9]. The most common bicycle infrastructure implemented in Victoria is a bicycle lane, typically a painted white line with a painted bicycle symbol along the left side of the kerbside lane. In some locations across Melbourne, the bicycle lanes are painted green to increase driver and cyclist awareness of the lane particularly, at busy or complex locations [10].

While cycle lanes are effective in providing separation of cyclists and vehicles, one of the major disadvantages is that they inevitably cross roads at various points, and interaction with vehicular traffic at intersections places cyclists at heightened risk. In many cases, bicycle lanes discontinue on approach to intersections. Indeed, along Melbourne's most used on-road commuter cyclist route, St Kilda Road, most mid-block bicycle lanes discontinue on approach to the intersection, and cycling infrastructure is absent from the holding area and through the intersection.

In some locations a bicycle storage box (see description in next paragraph) is provided at the intersection bar. According to the Australian and Victorian traffic engineering guidelines, at points where the road narrows, cyclists are expected to defend their space among moving vehicular traffic by positioning themselves in the centre of the lane [11] as the priority for space allocation on the roads is to vehicles [12]. However, where there are feeder lanes into the bicycle storage box, cyclist behaviour has been found to be more predictable than when the bicycle lane discontinues [13].

Bicycle storage boxes have been widely installed in Melbourne. Also called advanced stop lines or head start areas, bicycle boxes originated in the Netherlands. They are painted on the road at the front of the vehicular traffic lane at intersections and aim to create a separate space for cyclists to wait during the red light phase. The position increases driver awareness of the cyclist, thus increasing cyclist safety [6, 14].

Cycling infrastructure research in New Zealand identified the primary objectives of the boxes were to improve cyclists'

physical safety and reduce cyclists' perceived risk at intersections. The study found a reduction in driver-cyclist collisions after the installation of the box, and cyclists reported feeling safer. However, the authors reported that drivers did not like cyclists 'stacking' ahead of them and felt unsure or non-committal about the purpose and function of the box [15].

In Victoria, an additional intention of the boxes was to formalise, and in doing so legitimise, the informal behaviour of cyclists of rolling through to the front of traffic during the red light phase [16]. In addition, the boxes have the advantage of locating cyclists away from vehicle exhausts while waiting in traffic, and provide an opportunity for them to leave from the traffic lights first, ahead of vehicular traffic [12, 17].

For the bicycle storage box to be effective, the space must be kept clear for cyclists. Several studies have found that vehicle encroachment during the red light phase has created concern for cyclists. Newman found that driver intrusion did influence cyclist confidence and their position at the intersection. In video observations, cyclists were likely to use the box, whereas drivers were the least compliant and intruded on or obscured the cycling infrastructure [15]. A before-and-after observational study of bike storage box installations in the United States found that slightly more than half the vehicles observed (51.9%) encroached into the box [17]. In the United Kingdom, of 5114 cyclists observed, 36% experienced a vehicle encroaching into the bike storage box [13].

Driver and cyclist education about how to interact with the cycling infrastructure also influence compliance [13, 15, 17]. In Victoria, the current graduated licensing system is underpinned by the Victoria drivers licence handbook Road to Solo Driving. There are numerous references to bicycle lanes and appropriate driving behaviour when sharing the road with cyclists. However, there is limited information on broader cycling infrastructure, with only one reference made to bicycle storage boxes, referred to as 'head start' areas, with no information about appropriate driver behaviour at a bicycle storage box [18].

More extensive information about driver and cyclist behaviour, including an increase of penalties for encroaching into a bicycle storage box, has been available on the VicRoads website since changes to the Victorian road rules in November 2009. Drivers may be fined up to 10 penalty points (currently \$1168.20) [19, 20]. There are detailed instructions about the correct positioning of drivers and cyclists on the road with a clear, instructive animated graphic. However, this information is located on a cyclist-specific road rule site, and it is not known how many non-cycling drivers view this page.

The aim of this study was to evaluate cyclist and driver compliance at different cycling infrastructure treatments at signalised intersections. Given the increasing number of cyclists in Australia and the lack of research focused on the safety implications of cycling infrastructure, it was anticipated that the findings would contribute to knowledge about infrastructure use and highlight potential solutions to improve cyclist safety.

## Methods

This study was designed to assess the compliance of cyclists and drivers at signalled intersections with varied cycling infrastructure. The observation sites included three types of cycling infrastructure that have been implemented along the most frequently used on-road cyclist commuter routes in metropolitan Melbourne. A novel covert position was used to record the behaviours of all cyclists and drivers who entered the sites.

### Research design

This was a cross-sectional observational study of on-road commuter cyclists. The study was conducted in March 2009 at six sites along popular on-road commuter cyclist routes on St Kilda Road and Swanston Street [21]. All sites were within five kilometres of the central business district (CBD), as measured from the Melbourne Town Hall. Each observation was a three-hour recording repeated over six non-consecutive days either at 7-10am or 4-7pm, resulting in 18 hours of recordings per site. Given the time of the observations, it was assumed that most cyclists and drivers were commuting to or from work. It was not necessary to observe multiple approaches, as the peak flow of commuter cyclists travelled in one direction at all observed sites.

### Observation sites

Three types of cycling infrastructure at intersections were observed: a bicycle storage box in front of the left lane, a bicycle storage box in front of the centre lane and continuous green-painted bike lane. As the majority of the cyclist traffic flow is one way during peak hour travel times, only one approach was observed at each site. The three treatment types are illustrated in Figure 1.

#### *Bicycle storage box in front of the left lane*

Intersections with bicycle storage boxes in front of the left lane (Figure 1, diagram 1) were observed at two intersections on the most used on-road cycling commuter route in Melbourne, along St Kilda Road from the south-eastern suburbs of Melbourne [21]. Two sites were observed, one in the morning (in-bound) and one in the afternoon (out-bound). The signals at this intersection did not have a left-turn filter light. This is

the most common bicycle storage box position along the selected route.

#### *Bicycle storage box in front of the centre lane*

The second type of bicycle storage box (Figure 1, diagram 2) was also observed along St Kilda Road, and at these sites the bicycle storage box was located in front of the centre vehicular lane. The intersections with this infrastructure had a dedicated left-turn vehicle lane with a left turn filter light. The position of the centre storage box placed cyclists ahead of drivers who were continuing straight through the intersection.

For all bicycle storage box sites observed, there was no bike lane on the approach to the intersection. The mid-block bike lane discontinued prior to each observed site.

#### *Continuous bicycle lane*

The third type was green-painted bicycle lanes that continued from midblock to the intersection; the lane did not continue through the intersection, as shown in Figure 1 (diagram 3). These sites were located along Swanston Street to the north of the CBD. The lanes were located kerbside, parallel to the vehicular traffic, and were continuous with the mid-block Copenhagen-style bike lane. These sites did not have a bicycle storage box at the intersections.

### Procedures

A Sony DCR-SR62 video camera was positioned inside a small grey box and attached to a roadside sign post that gazetted parking time details. The camera position recorded the behaviours of all road users who entered the space, and continuous recording allowed detailed analysis of cyclist and driver behaviours. The covert positioning of the camera eliminated potential behavioural bias, as cyclists and drivers were unaware they were being filmed.

There were weather-related restrictions to the observations to minimise potential bias. Observations were not conducted on days over 35°C or when it rained during the morning observation period, as on these days there were lower numbers of cyclists and fewer female cyclists. Observations continued on the next suitable day.

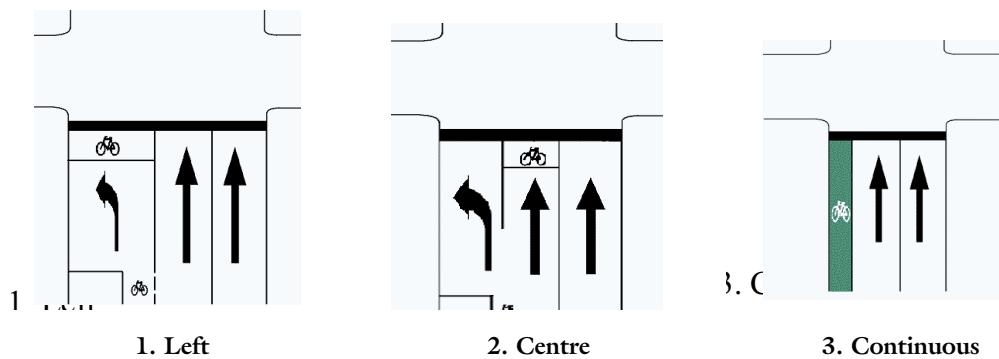


Figure 1. Cycling infrastructure observed

## Definitions of cyclist and driver compliance

Of interest was cyclist and driver compliance at the cycling infrastructure types when approaching a red light. At the bicycle storage boxes, cyclist compliance was defined as entering the bike storage box with at least one wheel in the box. For drivers, compliance was defined as stopping before the bicycle storage box, defined as the front wheels of the vehicle stopping before the white line of the box. It was possible that there may still be vehicle encroachment, with the bonnet of the vehicle entering the bicycle storage box; however, given the perspective recorded by the camera, the wheel-based classification was the only objective classification possible across all the sites. Only the first vehicle to approach the intersection was coded at all sites. Non-compliance was recorded when the wheels encroached into the box.

At the continuous bicycle lane, cyclist compliance was defined as staying within the bicycle lane. Cyclists who stopped in front of the continuous bicycle lane (i.e., in the pedestrian crossing or in the parallel vehicle lane) were coded as non-compliant. For drivers, compliance was defined as stopping parallel, with all wheels outside the bicycle lane. Drivers whose vehicle wheels encroached into the bicycle lane were coded non-compliant. It is possible that vehicle protrusions or mirrors may have entered the bicycle lane.

There is potential for coding bias in observational studies, particularly with a single researcher coding the data. In this study, compliance for both cyclists and drivers was coded separately by an independent research assistant for 6 hours (11.1%) of footage and analysed using the Kappa statistic. The inter-rater reliability was Kappa = 0.673 ( $p<0.001$ ), 95% CI (0.585-0.761). This measurement of agreement is statistically significant and can be interpreted as substantial [22].

## Results

Nine hours of footage was analysed for each of the six sites, for a total of 54 hours. A total of 2670 cyclists (including 1878 males and 792 females) and 1243 vehicles stopped at the intersection at the observation sites during the red light phase.

### Descriptive statistics

Cyclist and driver compliance rates were cross-tabulated with the three cycling infrastructure types as summarised in Table 1.

Compliance was greatest at the continuous lane location, with a high level of compliance by drivers and cyclists. In comparison, cyclists were more compliant than drivers at the bicycle storage box sites, regardless of the positioning of the box. Across the infrastructure types, the relative compliance was different for cyclists and drivers ( $\chi^2 = 16.217$ ,  $p<0.001$ ).

### Binary logistic regression – cyclists

Site infrastructure type, time of day and cyclist gender were included in a binary logistic regression with compliance (yes/no) as the outcome variable (see Table 2). A cut-off for predicted probability of compliance of 0.07 was used in the classification tables for the fitted model. The overall correct predictive percentage of the model was 67.4%, with sensitivity 63.8% and specificity 78.1%.

Infrastructure type had the strongest association with cyclist compliance. In particular, the compliance odds at the continuous bicycle lane was 12.4 times the compliance odds at the left bicycle storage box infrastructure. There was also an association with time of day and compliance odds, with the compliance odds 39.3% less in the afternoon compared with the morning. There was no statistically significant association between compliance and gender.

**Table 1. Descriptive statistics of cyclist and driver compliance at three cycling infrastructure types**

	Cyclists		Drivers	
	% compliant	Observed	% compliant	Observed
<b>Infrastructure</b>				
Left bicycle storage box	64.9%	1005	49.8%	275
Centre bicycle storage box	53.0%	614	49.6%	516
Continuous bicycle lane (green)	95.4%	1051	97.7%	452

**Table 2. Relative odds of compliance-related factors in the model – Cyclists**

		Relative odds of compliance	Statistical significance	95% C.I. for odds
<b>Infrastructure</b>				
Infrastructure	Centre vs left	0.686	0.000	0.556 0.848
Infrastructure	Continuous vs left	12.494	0.000	9.059 17.230
Time	pm vs am	0.607	0.005	0.496 0.744
Gender	Female vs male	0.926	0.478	0.749 1.145

## Binary logistic regression – drivers

A second binary logistic regression was constructed for drivers, including infrastructure and time of day, with compliance as the outcome variable (see Table 3). A cut-off for predicted probability of compliance of 0.07 was used in the classification tables for the fitted model. The overall correct predictive percentage of the model was 67.6%, with sensitivity 52.9% and specificity 97.5%.

Again, infrastructure type had the strongest association with driver compliance. In particular, the compliance odds at the continuous bicycle lane were 43.9 times the compliance odds at the left bicycle storage box infrastructure. The time of day and compliance association was similar to the cyclist rate, with drivers having an odds of compliance 32.0% lower in the afternoon compared with the morning.

## Discussion

Common cycling facilities such as bicycle lanes and bicycle storage boxes aim to separate cyclists and vehicles along mid-block and at critical locations; however, such infrastructure treatments are only effective if they result in appropriate behaviour. While there are some noted benefits of these treatments, little is known about their effect on behaviour. This study examined cyclist and driver compliance behaviour at three types of cycling infrastructure at signalled intersections.

Infrastructure type was the greatest predictor of compliance. Specifically, the continuous, green bicycle lane was associated with the highest levels of compliance by both groups of road users. A key point to note is that compliance creates different demands depending on the infrastructure type. The continuous bicycle lane was a continuation of the mid-block infrastructure, so drivers and cyclists continued to travel parallel with each other to the intersection. The only compliance requirements were that drivers did not encroach on the green lane when they turned left and cyclists maintained their position within the lane.

However, at the bicycle storage box sites, compliance does require a variation in travel behaviour between mid-block and intersection. Firstly, while drivers and cyclists travel in parallel when mid-block, compliance at the bicycle storage box requires drivers to stop behind the box, short of their ‘usual’ position at the intersection. Secondly, cyclists are required to move from travelling in parallel to the drivers to stop in front of the vehicle. This need for variation in behaviour may have contributed to

non-compliance, and it may be that cyclist infrastructure is perceived as less legitimate when it displaces drivers.

The continuous bike lane was painted green at both observed sites, so it is not possible to determine whether it was the continuous path or the painted colour or a combination of both elements that contributed more directly to higher compliance. The importance of colour to distinguish cycling infrastructure and discourage vehicle encroachment has also been identified at bicycle storage boxes [11,17]. Further research is needed to determine the role of coloured surface treatments for cyclist infrastructure and both cyclist and driver compliance.

At all bicycle storage box sites, the level of compliance of cyclists was higher than drivers. This may suggest that a high proportion of compliant cyclists perceived the boxes to provide a safe space to wait during the red light phase. It is not known why approximately half of drivers were non-compliant. Possible reasons may be lack of knowledge of the purpose of the boxes, disregard for the space if no cyclists are already present, failure to notice the infrastructure or acknowledge the space as legitimate, or failure to accept cyclists as legitimate road users. Further research is needed to determine the reasons for driver non-compliance. Time of day was a significant factor for both cyclists and drivers, as groups were more compliant in the mornings than the afternoons.

At the centre bicycle storage box sites, some cyclists were coded as non-compliant because they stopped behind the bicycle storage box in single file along the left side of the waiting vehicle, rather than in front, essentially creating an informal left-side bike lane. Further research is needed to determine cyclists’ motivations for this behaviour; possible motivations may include perception of safety, habit, lack of awareness of the function of the box or reluctance to impede drivers. Further research is also needed to determine the role of vehicle positioning on cyclists’ non-compliance.

In order to improve compliance we need a better understanding of the influencing factors. Recent changes to Victorian road rules increased the penalty for non-compliant drivers at bicycle storage boxes; however, there have been limited education and awareness campaigns about the changes, and to date the impact of the road rule changes on compliance is not known. It is likely that education and awareness programs that inform all road users of the function of the space will improve compliance.

**Table 3. Relative odds of compliance related factors in the model – Drivers**

		Relative odds of compliance	Statistical significance	95% C.I. for odds	
<b>Infrastructure</b>			0.000		
Infrastructure	Centre vs left	0.956	0.767	0.712	1.285
Infrastructure	Continuous vs left	43.866	0.000	22.436	85.766
Time	pm vs am	0.680	0.006	0.517	0.895

Compliance may be affected by additional factors such as vehicle type or the presence of other road users, and therefore available space, on arrival. This could be addressed with further analysis of the video observations. It is also possible that non-observable factors may also contribute to compliance, such as socio-economic status of the cyclist or driver, or perceptions of safety. Survey research is planned to explore these factors further.

## Conclusion

This study has provided a baseline measure of cyclist and driver compliance for three commonly used cycling infrastructure treatments. Highest compliance rates for both cyclists and drivers were observed for continuous bike lanes and during morning observation times. It is recommended that future research be conducted to identify reasons for non-compliance and to explore potential treatments to enhance compliance, including coloured bicycle storage boxes and continuous bicycle lanes.

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