



# Journal of the Australasian College of Road Safety

Formerly RoadWise – Australia's First Road Safety Journal



## Special Issue: Vehicle safety, technology and the future of cars

### Peer-reviewed papers

- Motorcyclist perceptions of risk when riding
- Computer modelling of a test device for investigating injury causes in vehicle rollovers
- Strapped for life or trapped: survey of drivers' knowledge levels and attitudes towards seatbelts and seatbelt law in Zimbabwe

### Contributed articles

- Reducing rear-end crashes with cooperative systems
- Autonomous emergency braking – the next seat belt?
- Motorcycle safety through smart technology
- Feature items from New Car Assessment Programs: Global NCAP; Australasian NCAP; ASEAN NCAP; Insurance Institute for Highway Safety; Euro NCAP; Japan NCAP; Korean NCAP; and Latin NCAP.
- The CITI Project - Australia's first cooperative intelligent transport system test facility for safety applications



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ANCAP Chief Executive Officer



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3M-ACRS

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1<sup>st</sup> April 2014



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

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The individual Team Leader from the winning project will **RECEIVE a trip to the USA** to attend the **45th ATSSA Annual Convention & Traffic Expo at Tampa, USA** between the 8th - 10th February, 2015. You will also visit **3M head office**. This individual will also present on their winning entry and international trip at the following ACRS Road Safety Conference in 2015



TO ENTER & MORE INFORMATION, VISIT  
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Entries open 1st April 2014 and close 5pm (EST), 15th August 2014.

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### Cover image

The establishment of NCAPs around the world has had a profound influence on the safety of vehicles which translates to the saving of many thousands of lives. Vehicles undergo stringent testing to determine their safety rating. The Australasian New Car Assessment Program (ANCAP) has been undertaking crash testing for more than 20 years. In this time, and in particular in the last decade, there has been huge improvement in the performance of car structures.

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

## From the President



Dear ACRS members,

This edition has a focus on vehicle safety, new technology and the future of cars.

We often overlook the role technology plays in the things we do. Road safety is no exception. Acceptance of seat belts for instance I suspect was enhanced

with the development of the inertia retractor, now a sophisticated explosive device which tightens the belt in the event of a crash in a fraction of a second. Inflatable seat belts are now installed in some aircraft seats and are available for rear seat car passengers.

Travel speeds on our roads are in many cases lower than they were decades ago. The cars we drive today and those we will drive in the future are more stable, significantly more crashworthy and are becoming less likely to crash into fixed objects or each other. They are more “friendly” to other road users and simpler to operate.

Many of the new technologies will come not only from the car industry, but from communications and sensing areas, and introduced not only by the car manufacturers but from new firms selling a mobility service of which a car may just be a generic shell.

The technologies will revolutionise the way we measure and insure our road travel and how we measure, report and regulate our ability to control that travel. Some of this will be rapid, some will take some adaptation.

Also in this edition are more papers from last year’s Adelaide Conference.

The road safety canvas is very broad; there are issues and solutions on many fronts. We welcome your comments and of course your participation in Chapter events.

*Lauchlan McIntosh AM FACRS  
ACRS President*

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## Diary

### **20 – 21 May 2014**

Innovating With Asia  
Perth Convention and Exhibition Centre, Western Australia  
<http://conference.crca.asn.au/index.php/about>

### **21 – 23 May 2014**

National Medicines Symposium: Medicines in Health –  
Shaping Our Future  
Brisbane Convention and Exhibition Centre  
Brisbane, Queensland  
<http://www.nps.org.au/about-us/what-we-do/campaigns-events/national-medicines-symposium>

### **1 – 4 June 2014**

Safer Roads; Healthier Communities  
Hosted by the Canadian Association of Road Safety  
Professionals and the British Columbia Injury Research and  
Prevention Unit  
Vancouver, British Columbia  
<http://www.carsp.ca/cmrcs.htm>

### **6 – 7 June 2014**

Trucking Australia  
Convention Centre, Hamilton Island  
Queensland  
<http://www.truck.net.au/public/trucking-australia>

### **10 – 11 July 2014**

7th Making Cities Liveable Conference  
Mantra on Salt Beach, Kingscliff,  
New South Wales  
<http://healthycities.com.au/>

### **7 – 11 September 2014**

21st World Congress on Intelligent Transport Systems  
Detroit, Michigan  
United States of America  
<https://www.its-australia.com.au/events/21st-world-congress-detroit-2014/>

### **10 – 11 September 2014**

Road Safety 5 International Conference: Improving Road  
Safety Together to Save Lives  
Manila, The Philippines  
<http://roadsafety-5conference.com/Homepage>

### **18 – 19 September 2014**

Occupational Safety in Transport Conference  
Crowne Plaza, Surfers Paradise  
Gold Coast, Queensland  
<http://ositconference.com/>

# Guest Editor



**Nicholas Clarke**

Chief Executive Officer, Australasian New Car Assessment Program (ANCAP)

Welcome to this special vehicle safety edition of the Australasian College of Road Safety Journal.

Many in the road safety space have, in one way or another, had something to do with the Australasian New Car Assessment Program (ANCAP) over the past two decades. Having been around since 1992, ANCAP has seen dramatic changes in the crashworthiness of new cars sold into the Australian and New Zealand markets during this time. In the last 2-3 years however, vehicle safety has moved at lightning speed.

We're all now well versed on the importance of passive vehicle safety features such as crumple zones, seat belts and airbags which provide protection if you have a crash, but the future of vehicle safety lies with active safety features - safety assist technologies which can prevent a crash from occurring.

Our sights - not only for ANCAP but for vehicle safety testing programs around the world - are therefore trained on technologies which see cars that react before the driver; cars that read the road; and in time, cars that can safely take their passengers from A to B without any driver intervention at all.

Fully autonomous cars are a little way off, but have you realised autonomy has already made its way into the cars available to us today? Lane-keep assist, adaptive cruise control and blind spot monitoring are safety assist technologies which have started the shift to autonomous cars. These are just an entree into what is in store for consumers in the coming years.

Of the nine vehicle safety testing programs around the world, we're all heading in the same direction. As we look back at the improvements our programs have made in providing consumers with safer cars and the downward trend in road deaths as a result, we need to look forward to the future improvements that can be made, and how programs such as ours can influence these improvements.

The demand for safer cars by Australian and New Zealand consumers is at a record level. This demand for safer cars means we cannot remain idle. Cars are becoming more sophisticated and so is our testing.

The papers within this edition of the Journal provide an outline of the shift that is occurring with vehicle safety testing worldwide and paints a picture of the international efforts to reduce road trauma. While each of our test programs adapts to the changing needs of its market, whether it be established or emerging, we each have the same goal - **to encourage manufacturers to build, and consumers to buy, the safest cars possible.** And, in the not too distant future, this may very well be through fully autonomous cars.



road safety : aviation : watercraft : defence : rail : fleets : associated fields

## 2014 Occupational Safety in Transport Conference 18-19 September 2014 – Crowne Plaza Surfers Paradise, Gold Coast



### Themes will include:

- Transport Safety Culture and Management
- Technology for the Improvement of Safety, Systems and Behaviour
- Transport Related Impairments and Return to Work Assessment Processes
- Industry Logistics and Transport Safety Risk
- Developing and Evaluating Safety Programs
- Transport Safety Innovations, Challenges and Opportunities

### Keynote speakers:

Colonel Simon Tuckerman, *Australian Defence Force.*  
Professor Ann Williamson, *University of NSW.*  
Stephanie Pratt, *U.S. National Institute for Occupational Safety and Health.*

### Who should attend:

- Fleet managers/coordinators
- Researchers and practitioners
- Policy and process developers
- Engineers
- Vehicle manufacturers
- Workplace health and safety officers
- Local and State government representatives
- Technology manufacturers and developers
- Transport logistics and operations specialists



### Registrations now open:

<http://ositconference.com>

Images courtesy of CARRS-Q, Port of Brisbane and the ADF.

# College news

## Head Office News

### Welcome to:

#### Corporate Members

In Gear Australia, Darwin  
VicRoads: Road safety - upgrade to silver

## Chapter reports

### New South Wales (Sydney) Chapter

The Sydney Chapter kicked off 2014 with two seminars capitalising on the visits of colleagues from the Department of Applied Mechanics at Chalmers University of Technology, Gothenburg, Sweden to member research groups.

On January 29, we joined Transport and Road Safety (TARS) Research, The University of New South Wales in hosting a seminar by Dr Marco Dozza, Assistant Professor, Traffic Safety Division on *Bicycle Safety: Naturalistic Cycling Studies in Europe*. Then on March 7, we joined Neuroscience Research Australia (NeuRA) in hosting a seminar by Helen Fagerlind, Research Area Manager, Road Safety Data from the Vehicle Safety Division on *Using Data from In-Depth Crash Investigations*.

Both seminars were well attended and offered welcome insights into technological advances in these fields, including in research applications, to help improve road user safety.

Our next meeting will be the Chapter AGM on April 30, which will have been held by the time of printing, so please visit our page on the ACRS website for updates.

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

### ACT and Region Chapter

#### Inquiries

During 2013, the ACT and Region Chapter made submissions to the ACT Speed Camera Performance Audit conducted by the ACT Auditor General; and to the

Inquiry into Vulnerable Road Users conducted by the ACT Legislative Committee Standing Committee on Planning, Environment and Territory and Municipal Services.

#### ACT Speed Camera Performance Audit

The Auditor General report entitled **Speed Cameras in the ACT** was tabled in the ACT Legislative Assembly on Thursday March 20, 2014. The report found that:

1. The ACT is unlikely to have the right number of speed cameras in the right places.
2. The effectiveness of speed cameras in reducing speed has not been established. Also, there has been no 'network-representative, speed monitoring system' which could be used to gauge the extent of the ACT's speeding problem. Therefore the extent of the problem or the impact of the Government's speed cameras on road safety cannot be determined.
3. Speed camera reliability is poor, particularly for mobile speed cameras. This has led to escalating maintenance costs, limited camera availability and a greater number of rejected infringements. Poor reliability has had no effect on the validity of infringements issued as the Government's verification (adjudication) procedures are robust. However, there is a high rejection rate of infringements in the verification process and this indicates inefficiencies.

The Auditor-General has made 16 recommendations for action to address audit findings. A key recommendation addresses the need for the ACT to develop a speed camera strategy. Copies of the report are available on line at <http://www.audit.act.gov.au/reports2014.html>

The ACT Government has commissioned a review by the University of NSW's Transport and Road Safety Research group. The study will consider the impact of speed cameras in the ACT on crashes and speeding, with findings due to be released by the middle of the year.

#### Vulnerable Road Users Inquiry

This Inquiry is still under way. The Chapter, represented by Chair, Eric Chalmers and Federal President, Lauchlan McIntosh, attended a hearing of the Inquiry and provided supporting information related to the Chapter's submission.

#### Older Road User Seminars

Working in conjunction with the Council of the Ageing (COTA) and other organisers of the 2014 ACT Senior

Citizens Week, the Chapter ran two identical seminars for senior drivers aimed at: providing information on driving for seniors; addressing any concerns they may have about driving; helping them monitor their driving; and answering questions about driving.

These were part of the Chapter's continued efforts to conduct seminars that will appeal to a wider range of the ACT and Regional community on issues that will assist in reducing deaths and serious injury. The seminars were held on March 17 and 19 in different locations in Canberra. Four organisations provided information to 45 attendees at the first seminar and 51 at the second. They were: the ACT Road Safety Unit, ACT Justice and Community Safety Directorate; Professor Kaarin Anstey, Director, Centre for Research on Ageing, Health and Wellbeing, ANU; the ACT Driver Assessment and Rehabilitation Service; and the Australian Federal Police Traffic Operations.

All presenters spoke with compassion about the issues which face older drivers without backing away from the serious aspects that needed to be addressed. Coincidentally, but not unexpectedly, each speaker reaffirmed the essential messages of the others.



**Mr Brian McKinlay and Susan Humphries from the ACT Driver Assessment and Rehabilitation Service described the process of obtaining a driver assessment and the assistance they can provide to senior drivers.**

Presenters recognised that to most people driving represents not only a means of transportation but a symbol of independence and self-reliance; and it can be crucial for performing shopping, attending appointments and for visiting family and friends. Older people who are mobile and drive may have fewer health problems. Driving one's own vehicle is associated with higher levels of life satisfaction, less loneliness and better perceived control.

Attendees took the opportunity to question the presenters at both sessions. While one seminar focussed on issues associated with medical and practical driving issues, some attendees at the other raised the question of alternative ways to maintain mobility. These mainly related to questions about the adequacy and frequency of weekday public transport for seniors without a car. Another proposed that people should be encouraged to cycle earlier in life and continue in their older age.

The principal themes of speakers were:

- While older road users (drivers, passengers and pedestrians) are not over-represented in ACT crash statistics, from a national perspective, older drivers are the fastest growing segment of the driving population and nationally total accident and injury rates are **increasing** for older drivers while **decreasing** for all other age-groups.
- Older drivers have fewer accidents as a result of infringements (speeding, alcohol etc) and more as a result of errors but more than 50% of older driver accidents occur at intersections, or while merging and most involve multiple vehicles.
- Ageing of a normal person without major medical problems, naturally involves reductions in visual physical and cognitive processes which affect older drivers' capacity to drive safely. Visual impairment increases with age. Physical functioning sees increased prevalence of systemic disease, physical frailty and joint stiffness. Cognitive ability deteriorations are: slower reaction time and processing speed; and poorer performance on visual spatial tasks and executive function measures.

Research undertaken by the Centre for Research on Ageing, Health and Wellbeing found:

- Critical errors during an on-road driving test of normal drivers increased with age.
- Participants were not demented, they lived in the community, drove regularly and had stable verbal ability (vocabulary, general knowledge, professional expertise). They had slowing of processing speed and reaction time, more variability in responding with some memory decline.
- Participants also had reduced executive function in terms of co-ordination of higher level information, planning responses and response inhibition.
- Adults age at different rates and should be assessed individually.
- Studies found poorer processing speed and visuo-cognitive abilities but *not memory*, are associated with more errors in normal elderly. Slowed processing speed and reaction time, reduced visual processing, executive function and visual search are important. Older drivers have 24% more safety errors overall. Lane change, lane observance, turns and pulling away from the curb are the more serious errors. They have 2.6 more errors per five year age increment. And among older drivers, poorer cognition is associated with more errors.

- Self-rating of hazard testing showed there was no correlation between performance and self-ratings. This is because without a crash, there is no feedback of missing a hazard, and this reduces opportunity to learn. Tests were undertaken with 305 drivers who performed video based hazard perception tasks and were asked to rate how well they did.
- Dementia will cause unsafe driving as the disease progresses and the crash risk is proportional to the severity of dementia. In the early stages driving may be OK. The issue is how to identify when driving is no longer safe.



**Professor Kaarin Anstey, Director, Centre for Research on Ageing, Health and Wellbeing, ANU addresses the audience**

### Overall Conclusions

As we age changes in motor function can include: decreased movement, decline in muscle strength and endurance, increases in reaction time, changes to sensation and changes in awareness of positioning of limbs. These changes impact on gripping and turning the steering wheel, difficulty operating pedals in a smooth controlled manner, backing and parking a vehicle and transferring in and out of the vehicle. Changes in vision can decrease peripheral vision, decrease ability to see at night, increase sensitivity

to glare and decrease depth perception. This results in drivers having difficulty in their ability to see signs, judge distances, and see pedestrians and other objects at night. Changes in cognition can affect our memory skills (STM), slow the processing of information, cause changes in attention with distractibility and in judgement and planning skills, in problem solving and the ability to anticipate, and in spatial thinking eg navigating from point A to point B. It may also lead to reduced concentration skills and a reduced ability to multitask.

### The Future

- Continue to promote road safety knowledge among the senior driving population in the ACT and surrounding NSW region.
- Promote the activities of the Driver Assessment and Rehabilitation Service programs in the ACT and New South Wales among drivers and medical practitioners.
- Promote use of the 18+ card as an alternative for identification in place of the Driver Licence; and the use of bus passes, community transport and taxi vouchers through government assistance schemes.
- Develop a means for road rules and changes to be brought to the attention of older drivers.
- Encourage older drivers to be honest with their doctors, discuss driving with family members, consider a 'Special Licence' and to prepare for possible withdrawal of their driving licence.
- Advocate that road safety authorities undertake research into reducing the number and severity of the crash types involving older drivers.
- Road safety organisations should continue to work closely with Alzheimer's Australia and other specialist bodies servicing the older age community.
- Raise issues by attendees about public transport.

# Other news

## 3M-ACRS Diamond Road Safety Award

Applications are being called for the 2014 3M-ACRS Diamond Road Safety Award.

The 3M-ACRS Diamond Road Safety award calls for any road safety practitioner from the public or private sectors to submit highly innovative, cost-effective road safety

initiatives/programmes which they have recently developed that stand out from standard, everyday practice and deliver significant improvements in road safety for the community.

An individual team leader from the winning project will receive a trip to the USA to attend the 45th ATSSA Annual Convention and Traffic Expo in 2015 at Tampa and to 3M Global Headquarters in Minnesota USA. This individual

will also present on their winning entry and international trip at the following ACRS Road Safety Conference in 2015.

The winning entry will be announced in the latter part of 2014, when all eligible members of the winning project will be presented with the 3M-ACRS Diamond Road Safety Award.

For further information go to: <http://acrs.org.au/awards/>

## Austrroads publication

Methods for reducing speeds on rural roads - compendium of good practice

This compendium presents information on speed as a contributor to rural road crashes. It provides information on treatments that can be used to address speed, either at key locations (curves, intersections or the approach to towns) or for routes in general. The main focus is on road engineering-based treatments, but information is also provided on other approaches that may be used (e.g. enforcement and in-vehicle devices).

Detailed information is provided on almost 30 road engineering treatments that may be used to reduce speeds at key locations on rural roads. Information is presented on the speed and crash reduction effectiveness of commonly used treatments. These include advance warning signs, chevron alignment markers, and advisory speed signs at curves; advance warning signs and roundabouts at intersections; and advance warning signs and buffer zones on the approach to towns.

Emerging treatments have been identified, although less reliable information is available on their effectiveness. New and promising treatments include vehicle-activated signs and route-based curve treatments at curves; speed management and vehicle-activated signs at rural intersections; and rural gateway/threshold treatments on the entry to small towns. Other treatments require further investigation, but show some promise. These include in-vehicle speed warning systems for curves (and potentially other locations on rural roads); removing 'excess' sight distance at intersections, and methods to highlight the presence of intersections; and road narrowing combined with reduced speed limits.

<https://www.onlinepublications.austrroads.com.au/items/AP-R449-14>

**Access the Road Safety Risk Manager online!**

The Road Safety Risk Manager (RSRM) is a powerful tool that enables users to proactively assess road safety hazards and prioritise sites for treatment. It may also be used for prioritising maintenance activities.

The RSRM takes a risk management approach, with the aim of maximising crash risk reduction on the road network for available budgets.

The RSRM is able to be accessed online, via ARRB's hosting service. With assessments taking only 5-10 minutes, the online version of RSRM provides a fast, easy and cost-effective way to assess and manage road safety risks.

For more information about RSRM, phone the Road Management Support team on 1800 811 471 or email us at [subscriptions@arrb.com.au](mailto:subscriptions@arrb.com.au)

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# Peer-reviewed papers

## Motorcyclist perceptions of risk when riding

by Adrian Weissenfeld, <sup>1</sup> Matthew Baldock <sup>1</sup> and Timothy Paul Hutchinson<sup>1</sup>

<sup>1</sup> Centre for Automotive Safety Research, University of Adelaide, South Australia  
This peer reviewed paper was presented at the ACRS 2013 conference, held in Adelaide, South Australia, 6-8 November, 2013

### Abstract

The aim of this study was to explore the perceptions that a sample of South Australian motorcyclists have of the greatest risks to themselves whilst riding on the road. This was inclusive of both commuting and recreational riding.

The analysis was based on the self-reported responses to a questionnaire being used in an ongoing study examining the human factors involved in motorcycling safety and behaviour. Participants responded to an open ended question of: what are the greatest risks to motorcyclists on the road today? Flyers placed on parked motorcycles in the Adelaide Central Business District, presentations at social motorcycle clubs and advertising on online forums provided a total of 72 participants. Age and riding experience of the motorcyclists varied considerably, with the age ranging from 19 to 76 years (mean=49.2, SD=15.4), riding experience from 0.5 to 60 years (mean=19.8, SD=16.6), and average riding each week from 1 to 30 hours (mean=6.2, SD=4.5).

The responses fell across seven distinct themes: other road users, the motorcyclists themselves, aspects of the motorcycle, road surface conditions, road design hazards, roadside environment hazards and policing. Age and riding experience were associated with what riders chose as being most important for motorcyclist safety. Differences between objectively researched hazards and subjectively perceived hazards are discussed.

The results provide some insight into what motorcyclists consider to be the greatest threats to themselves and suggest some directions for future research.

### Keywords

Motorcyclists, Risk perception, Hazard identification

### Introduction

Motorcyclists continue to have the highest risk of injury or fatality of any road users on Australian roads. The statistical risk of injury and fatality from crashing is well documented, with the Australian rate of a motorcycle fatality per distance travelled at 30 times the rate of car occupants, and approximately 41 times higher for a serious injury [6]. However, the risks as perceived by the riders themselves are less well understood. This paper aims to present what riders consider to be the greatest risk to themselves while riding.

A better understanding of the hazards and risks that motorcyclists are exposed to, as identified by motorcyclists themselves, is important for a number of reasons. First, there are road hazards and risks to motorcyclists that are not experienced by other road users. These motorcycle specific hazards and risks need to be understood better in order to meet the goals of a safe system approach to road safety for all road users, and to better inform those who are deciding policy and allocation of infrastructure resources.

Secondly, it may be the case that the hazards and risks identified may change or be influenced by motorcyclist age and riding experience (and social or group identity). This may have some implications for safety interventions targeted at motorcyclists of specific age groups or motorcyclists of differing riding experience.

Furthermore there may be differences between objectively reported risks identified in research and the subjectively identified risks experienced by motorcyclists. If there are differences between the actual hazards to motorcyclists and the hazards that motorcyclists perceive on the road, then this may itself be a safety risk, especially if the discrepancy is pronounced for younger or novice riders. Such a discrepancy could have implications for training.

## Hazard perception and risks specific to motorcyclists

It is important to distinguish between the hazards that motorcyclists are exposed to and those of other road users. Hazard perception is defined as the ability to read the road and anticipate forthcoming events [9]. Recent research into the number and types of identified hazards has suggested that motorcyclists perceive more hazards than car drivers do, and have a more flexible visual search pattern than other road users [11, 5, 7]. A study by Rosenbloom [11], using a video based driving simulator, showed that motorcyclists have a faster response to hazards than non-motorcyclists, while Hosking [5], using a motorcycle simulator, found that motorcyclists with more riding and driving experience had a faster response to hazards and exhibited a more flexible visual scanning pattern than motorcyclists with less riding and driving experience. Similar results were found by Liu [7], whose study which also used a motorcycle simulator, showed that the more experienced motorcyclists crashed less often, received better performance evaluation and approached hazards at more appropriate speeds than less experienced motorcyclists.

Research by Hosking [5] suggests that the differences in the identification of, and response to, hazards between car drivers and motorcyclists are due to several factors, including the need to detect a much larger set of hazards (including many that are not relevant to a car driver), and the increased vulnerability of motorcyclists if involved in a crash. It is suggested that these factors increase the importance of developing visual search strategies that are much more responsive to changing road conditions and hazardous events. Motorcyclists must be able to detect a larger set of hazards than car drivers, with those hazards having a different priority for motorcyclists. For example, road surface hazards, while only a low-priority for car driver safety, can severely impact a rider's ability to stay upright.

### The influence of age and experience on the identification of particular hazards

Previous studies that have examined hazard perception have typically used a measure of reaction time, gaze fixation or response to a hazard identified in a simulator or video footage [3, 4, 5, 7]. While it has been shown in using these methods that more driving experience can improve hazard perception in drivers [11] the examination of the influence of age or experience on motorcycling hazard perception has given conflicting results.

The present study, rather than examining response to simulators or video footage, instead focuses on the hazards that are identified by motorcyclists in their real world riding experiences. Age and experience are then examined in terms of differences in which hazards and

risks are mentioned the most often. This approach differs significantly to the previously mentioned studies which focus more on the influence of experience or age on reaction time (and gaze fixation) to the identification of simulated hazards.

### The potential disparity between subjectively and objectively identified hazards

An indication of the actual hazards and risks that motorcyclists experience comes from the Motorcycle Accidents In-Depth Study [8]. The MAIDS was an in-depth study of motorcycle crashes conducted in Europe. The study analysed 921 motorcycle and moped crashes during the period 1999 to 2000 in five sampling areas located in France, Germany, Netherlands, Spain and Italy. The study found that the primary factor contributing to the majority of crashes was human error (a combined 87.9%), coming first from other road users (50.5%), and then from motorcyclists themselves (37.4%). Environmental factors were the primary causal factor in 7.7% of all cases, while vehicle factors accounted for 0.3% of primary causal factors.

The most frequent human error made by other road users was a perception failure to see the motorcyclists within the traffic environment due to lack of attention, temporary view obstruction, or the low conspicuity of the motorcyclist. The most frequent human error made by the motorcyclist was a decision failure, with the rider failing to make the correct decision to avoid a dangerous condition based on their strategy. Environmental factors included such things as roadway design defects, roadway maintenance, temporary traffic hazard obstructions including construction and maintenance, defective traffic controls and weather related problems. One of the aims of the present study was to see how the hazards and risks identified by a sample of motorcyclists align with the factors identified as contributing to crashes in the MAIDS study.

## Approach

In order to gain a better understanding of the hazards and risks that motorcyclists are exposed to, this paper will present the views of what a sample of motorcyclists in South Australia consider to cause the greatest risks when riding. The question of "What are the greatest risks to motorcyclists on the road today?" will be analysed and discussed in the context of the types of hazards that are identified, while looking at whether age or riding experience will influence which hazards are considered important. Finally the consistency between objectively identified hazards (from MAIDS) and the subjectively perceived hazards will be discussed.

## Methodology

### Sample

Participants were recruited using multiple methods in an ongoing study examining the human factors involved in motorcycling safety and behaviour. Flyers placed on parked motorcycles in the Adelaide CBD during the hours from 9am to 5pm, presentations at social motorcycle clubs, and advertising on online forums provided a total of 72 participants. Data was collected over a six month period from November 2012 to April 2013. Age and riding experience of the participants varied considerably, with the age ranging from 19 to 76 years (mean=49.2, SD=15.4), riding experience from 0.5 to 60 years (mean=19.8, SD=16.6), and average riding each week from 1 to 30 hours (mean=6.2, SD=4.5).

### Creating age groups

Due to the large variation in the age and riding experience of the participants and the high proportion of participants from the older demographic, two age groups were created for the analysis. Age groups consisting of those who were over 40 years as “older” and those who were under 40 years as “younger”, as presented in Table 1. It can be seen that the majority of the sample of participants were generally older, more experienced motorcyclists.

**Table 1: Summary of participant demographics by younger and older age group; means (standard deviations)**

	Younger (n=16)	Older (n=56)
Age	25.6 (5.1)	56.4 (8.7)
Riding experience (years)	3.4 (2.2)	25.1 (15.5)
Years not riding	0 (0)	7.8 (8.7)
Average riding hours per week	6.5 (6.7)	6.2 (3.6)

### Materials

A questionnaire used as part of an ongoing study collected information including demographic details, active and inactive riding experience in years, average weekly riding in hours and purpose, licence type and motorcycle type. Participants responded to an open ended question of “what are the greatest risks to motorcyclists on the road today?”

### Research procedure

#### Identifying themes and risk items

An initial processing phase consisted of analysing the thematic content of all the responses given by the participants. The type of response varied, with some

participants giving a one word identification of a risk, while others responded in the form of sentences describing the context and detail of the identified risk. Responses were analysed and coded by the paper’s first author.

The responses were then organised into themes. Within each theme there were specific risk items that were consistently mentioned, or the risks were described in the context of the theme. These provided the main categories of risk within each theme. For example, for the theme of other road users, the main risk categories were behavioural; attitudinal; and inattention-related. Each risk item was allocated to a risk category, with three to five risk categories for each theme.

The data was then disaggregated by age group and then by riding experience to examine how the themes were distributed across differing age and riding experience groups. The riding experience in years was separated into five groups: 0 to 1 years, 2 to 5 years, 6 to 10 years, 11 to 20 years, and 21 or more years.

## Results

From the 175 responses provided there were seven distinct themes identified: other road users, motorcyclists themselves (usually referring to other motorcyclists), aspects of the motorcycle, policing, road surface conditions, road design hazards, and roadside environment hazards. The themes one to four were self-explanatory, with a direct reference to the context of: other road users, motorcyclists themselves, aspects of the motorcycle and to policing procedures. The remaining three themes were created by referring to definitions drawn from AUSTRROADS “Guide to road design” publications (Parts 6 and 6b) [13, 14]. These three themes were each related to different aspects of the road: road surface conditions, road design hazards and roadside furniture.

The seven identified themes and the number of associated risk items for each are shown in Table 2. The theme with the highest number of risk items associated with it was “other road users” with 75 risk items identified. This was followed by “road surface conditions” with 35 items mentioned, then “motorcyclists themselves” was the theme with the third highest risk item count (24 items). Combining the three themes associated with the road gives a total of 65 items (37.2% of total responses), making the total number of risk items associated with the road second only to the number of risk items associated with other road users.

**Table 2: Identified themes and their associated risk categories**

Theme	Risk category	Item count	% of theme total
<b>Other road users</b> n=75 (42.9%)	- Inattention	28	37.3
	- Attitude	11	14.7
	- Behavioural	36	48.0
<b>Motorcyclists themselves</b> n=24 (13.7%)	- Inattention	3	12.5
	- Attitude	2	8.3
	- Behavioural	17	70.8
	- Training	2	8.3
<b>Aspects of the motorcycle</b> n=8 (4.6%)	- Small size	2	25.0
	- Quiet exhausts	2	25.0
	- Conspicuity	2	25.0
	- Cost of gear	2	25.0
<b>Policing</b> n=3 (1.7%)	- Attitude (biased against MC)	1	33.3
	- Reliance on cameras	1	33.3
	- Laws (preventing full use of MC)	1	33.3
<b>Road surface conditions</b> n=35 (20%)	- Badly maintained (surface)	18	51.4
	- Potholes	6	17.1
	- Bad repairs (friction changes)	9	25.7
	- Oil/diesel spills	2	5.7
<b>Road design hazards</b> n=19 (10.9%)	- Lane width	2	10.5
	- Manholes	5	26.3
	- Reflective markings (when wet)	7	36.8
	- General design	4	21.1
	- Poor/missing signage	1	5.3
<b>Roadside environment hazards</b> n=11 (6.3%)	- Roadside barriers	5	45.5
	- Debris on road	2	18.2
	- Close roadside furniture	2	18.2
	- Weather (run-off)	2	18.2
<b>Total Risk Items= 175</b>			

As each theme was comprised of differing categories of risk, the next stage of the analysis was to examine the risk categories by the frequency of items within a category and their percentage of the theme total. For the theme of “other road users”, the behavioural risk items accounted for almost half of the items mentioned, with a total of 75 items. These included the behaviour, in general, of cyclists (n=4), heavy vehicles (n=3), cars (n=12), and also specific driving behaviours such as not using head checks when changing lanes (n=8), using mobile phones (n=3) and crossing solid white lines when cornering (n=4). Inattention was mentioned as a risk item for other road users 28 times; 37.3% of the theme total. The remaining risk item associated with other road users was “attitude”. This consisted of aggressive and negative attitudes towards motorcyclists, as well as reluctance to accept motorcyclists as valid road users and to respect their “space” on the road. “Space” on the road was used as a reference to the safe following or overtaking distance that would be shown to other road users, or a “buffer zone”, as well as to the legitimate right to be on the road.

The theme of “motorcyclists themselves” had 17 behavioural risk items accounting for 70.8% of the theme total. These consisted of behaviours such as riding beyond one’s ability (n=5), racing/speeding (n=5), weaving through traffic (n=3) and general risk taking or not wearing correct protective gear (n=4). Inattention was the next highest risk factor, mentioned three times (12.5% of the theme total), followed by attitude, poor and over-confidence (n=2); and then by training (n=2), specifically the lack of good training for returning riders.

“Aspects of the motorcycle” had a total of eight risk items. The small size of scooters accounted for half of the risk items, with their lack of power and conspicuity mentioned four times. The lack of noise from the quieter exhausts of newer motorcycles was mentioned twice, with participants feeling it was a risk as other road users were less likely to hear them approaching. The remaining two risk items were related to the high cost of protective gear preventing its purchase and use (both times mentioned by scooter riders).

The theme of “road surface conditions” had a total of 35 risk items associated with it. Over half of the risk items (51.4%) were related to the poor maintenance of road surfaces. Bad repairs resulting in surface friction changes were mentioned nine times (25.7%), potholes were mentioned specifically six times (17.1%), and oil or diesel spills on the road accounted for the remaining two risk items.

For the theme of “road design hazards” there were a total of 19 risk items spread over five risk categories. The highest reported risk item was “reflective markings” (n=7) accounting for 36.8% of the theme total. This category included the raised safety bars on the median strip, and

the white lines and reflective “cat’s eyes” when the roads were wet. Manholes were the next highest risk item for this category, mentioned five times (26.3%). The sunken or lowered surface of the manholes in contrast to the road, their slippery surface, and the excessive number were all mentioned as a risk. The general design of the roads, as being biased towards cars and against motorcycles, was mentioned four times (21.1% of theme total), while the width of road lanes particularly when cars are parked was mentioned twice. Poor or missing signage was mentioned once.

The theme of “roadside environment hazards” consisted of 11 risk items. The most mentioned risk item was for roadside barriers (5 items, 45% of the theme total). These included Wire Rope Safety Barriers (WRSB) and ARMC0 metal safety barriers. Close and aggressive roadside furniture including “stobie” utility poles, trees and vegetation, particularly on blind corners, were mentioned twice; wildlife and debris on the road were mentioned twice; and the build-up of water on corners, due to ineffective storm water run-off, was mentioned twice.

The final theme of “policing” contained only three risk items. One item was related to perceived over-zealous “revenue-raising” attitudes targeted at motorcyclists; one item was related to the lack of police presence, with cameras declared to be a poor substitute; and one item was related to laws preventing the full use of the scooter/motorcycle in heavy traffic conditions (using bike/bus lanes, lane splitting).

### Distribution of themes across age groups

The next stage of the analysis was to examine whether particular themes were related to certain age groups. This analysis focused on the themes, rather than the particular risk items that comprised them. Due to the different numbers of participants in the two age groups the proportion (percentage) of responses, rather than response frequencies, for each theme are presented. Table 3 shows the distribution of responses for younger (under 40 years) and older (40 years and over) groups across the

seven themes, with the percentage of responses for each theme. The highest three responses for each age group are highlighted.

**Table 3: Age group distribution - percentage of responses by theme for each age group**

Theme	Younger (n=35)	Older (n=140)
Other road users	<b>34.3</b>	<b>45.0</b>
Motorcyclists themselves	11.4	<b>14.3</b>
Aspects of the motorcycle	14.3	2.1
Policing	2.9	1.4
Road surface conditions	<b>17.1</b>	<b>21.4</b>
Road design hazards	<b>17.1</b>	8.6
Roadside environment hazards	2.9	7.1
Total	100	100

The highest percentage of responses for both age groups was for the theme “other road users”, with 34.3% of total responses for the younger age group and 45.0% of total responses for the older age group. The theme of “road surface conditions” was the next highest response for both age groups, with “road design hazards” for the younger age group and “motorcyclists themselves” as the third highest response for the older age group. The small number of participants in the younger age group (n = 16) mean that this can only be treated as a preliminary analysis, in need of further examination with a larger sample.

### Distribution of themes across experience groups

The next stage in the analysis was to examine how the responses and themes were distributed across differing riding experience groups. Table 4 shows the distribution

**Table 4: Experience group distribution - percentage of responses by theme for each experience group**

Theme	0 - 1 year (n=11)	2 - 5 years (n=20)	6 - 10 years (n=19)	11 - 20 years (n=62)	21 + years (n=63)
Other road users	<b>18.2</b>	<b>40.0</b>	<b>57.9</b>	<b>40.3</b>	<b>46.0</b>
Motorcyclists themselves	9.1	<b>20.0</b>	5.3	<b>16.1</b>	<b>12.7</b>
Aspects of the motorcycle	<b>27.3</b>	10.0	0.0	3.2	1.6
Policing	0.0	5.0	5.3	0.0	1.6
Road surface conditions	9.1	<b>15.0</b>	<b>15.8</b>	<b>19.4</b>	<b>25.4</b>
Road design hazards	<b>36.4</b>	10.0	5.3	12.9	6.3
Roadside environment hazards	0.0	0.0	<b>10.5</b>	8.1	6.3

of responses for each experience group across the seven themes, with the percentage of responses for each theme. The highest three responses for each experience group are highlighted.

The theme of “other road users” had the highest percentage of responses for all experience groups with the exception of the 0 to 1 year group, which had “road design hazards” as the highest percentage response (36.4%), followed by “aspects of the motorcycle” (27.3%). The theme of “motorcyclists themselves” was the second highest response for the 2 to 5 year experience group, and the third highest response for the two groups with the most riding experience. The theme of “road surface conditions” was in the top three responses for all experience groups with the exception of the 0 to 1 year group. However, due to the constraints on the sample with a low representation of participants with lesser experience and younger age this should only be treated as a preliminary analysis.

## Discussion

### Identification of hazards

The results are consistent with previous studies showing the high level of attention that motorcyclists allocate to risks associated with the road in general, particularly road surface hazards, and also the risks associated with other road users [5, 11, 7]. This may reflect a high degree of hazard perception, or, more likely, hazard perception more specific to the risks most relevant to motorcyclists. Although it was not possible to compare the identified hazards with what other road users would identify, the study does highlight the significance that motorcyclists place on other road users and on the condition of the road surface as potential hazards.

### Differences between the age and experience groups

In terms of the differences between the age groups in where the remaining highest risk themes were identified, the younger age group were more concerned with design aspects of the road, particularly items that affected the friction when wet, such as manholes and line markings. The older age group was more concerned with the road surface hazards, such as potholes and poorly maintained or repaired roads. This difference in perceived hazards for the younger and older motorcyclists may reflect the difference that riding experience and different skill levels make. The concept of having an element of control over the risks may also be relevant here, with the ability to control some risks and not others guiding attention to what is considered more of a risk [2].

While it was not possible to track and examine how the sources of risk change over time for individuals, comparing the low experience groups with the higher experience

groups appears to show some differences in where the main concerns are. For motorcyclists with less riding experience it appeared that aspects of the road design and of the motorcycle were the greatest concern. Motorcyclists with more experience tended to be more concerned, again, with other road users, motorcyclists themselves and the road surface conditions.

A further issue to consider in how risk is identified and experienced by motorcyclists is the concept of group identity and the role that this plays in assigning blame or attributing the source of risk. This includes the aligning of self-identity and blame with particular in and out-groups; between car drivers and motorcyclists, between younger and older motorcyclists, and high and low risk takers. Which group one identifies themselves with will in part dictate where one will perceive the greatest risk [12]. It is possible that group identity, or “us and them” thinking, may also be a factor that tends to identify other road users as the bigger risk, similar to findings from Musselwhite [10]. The risk theme of motorcyclists themselves was third highest for the older age group, which may be indicative of another in-and-out group situation, this time between younger riders riding beyond their means or racing and the more responsible experienced riders who are more concerned with road craft [2].

### Consistency with hazards identified in MAIDS

There were some differences and some similarities with the primary contributing factors identified in the MAIDS report [8]. Other road users were identified in the MAIDS report as a primary contributing factor in 50.5% of crashes and they were the highest mentioned theme accounting for 42.9% of the total responses in the present study. However, while motorcyclists were identified as the primary contributing factor in 37.4% of the cases in the MAIDS study, they comprised only 13.7% of this sample of responses. This suggests an inconsistency between perceived and actual risks. Another possibility is that the wording of the original question may have influenced the responses, particularly in regard to the category of “motorcyclists themselves”. Specifically, the question “What are the greatest risks to motorcyclists?” may have led respondents to externalise the responses to factors that have a direct effect on them, rather than if the question was posed in the form “What are the primary crash causation factors, or what are the greatest risks to motorcycle safety?”

A further difference can be seen in the environmental factors identified in the MAIDS and the present study. While the environmental primary causal factors identified in MAIDS were 7.7% of all cases and 14.6% of all other contributing factors, road condition, design and roadside environmental hazards accounted for 37.2% of the total risk factors in the present study.

These differences between the objectively reported crash causal factors of motorcyclists and environmental factors with the subjectively identified risk factors may suggest a possible opportunity for education and training. Providing accurate information of crash causation in motorcycling licensing and training courses, and helping to identify where the main risks for crashes are for motorcyclists of differing age or experience groups, may help in keeping focus and attention on the most relevant hazards while riding. An examination in more detail of the types of human failure factors identified in the MAIDS report (perception, comprehension, decision and reaction failures), as compared with the perceived risk items associated with other road users and motorcyclists themselves using the present study's methodology, may also be a useful avenue for future research.

The findings from this study may be of help towards the overall goal of making the roads safer for all road users. Taking into consideration the safe system approach to road safety [1], there is the importance of designing a road environment and maintaining a road surface condition that accommodates all road users as equally as possible. There is also the challenge of shifting the mind set of all road users to see the traffic environment as a more of a shared space, so as to reduce some of the competitive and aggressive attitudes and behaviours between different types of road users [10].

## Limitations

There are limitations to this study that may threaten the degree to which the results can be generalised to the entire motorcycling population. The majority of participants were from the older age group and, although there are positive aspects to this, such as the increased identification of differing types of risks that years of riding experience exposes one to, it also limits what can be said about which risks are more important to riders of less experience or of a younger age.

The method of participant recruitment may also be a factor that could add bias to the results. By focusing recruitment on the Adelaide CBD there may be an over-representation of commuting riders with recreational only riders less well represented, although the recruitment from social motorcycle clubs and internet forums added to the balance between commuting and recreational motorcyclists. There is also the problem of response bias, with participants who agreed to take part in the study not necessarily representative of the motorcycling population as a whole.

A further potential limitation to the study comes from the methods used in coding of the themes and risk items. The use of thematic analysis software may have provided differing risk themes and categories. Further reliability and consistency testing of the themes may prove useful in improving the generalisability of the results.

## Conclusions and future research

In conclusion, this study provided some insight into what motorcyclists consider to be the greatest risks on the road. The identified differences between the objectively reported crash causal factors of motorcyclists with the subjectively identified risk factors may suggest a possible opportunity for education and training. Ensuring that accurate information of crash causation is included in motorcycling licensing and training courses, and helping to identify where the main risks for crashes are for motorcyclists of differing age or experience groups, may help in keeping focus and attention on the most relevant hazards while riding.

The results of this study may prove useful in the consideration of infrastructure resources, with the importance of the road surface conditions as potential sources of risk highlighted for motorcyclists. The use of media campaigns to address the issues of risk from other road users, particularly due to inattention and competitive or aggressive attitude, may also be of some benefit. Further work could be done to explore how perceptions of risk change over time with age and experience. A more detailed comparison between primary and contributing motorcycle crash causal factors, the types of human failure factors (perception, comprehension, decision and reaction failures), with the perceived risk factors of motorcyclists may be of benefit to assess the degree to which they align. By using a more representative sample it may also be useful to explore the effect that age and riding experience have in identifying and managing risk, and in how this may change throughout a motorcyclist's riding career.

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# Computer modelling of a test device for investigating injury causes in vehicle rollovers

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## Abstract

Vehicle rollovers account for a large percentage of the total fatalities in vehicle crashes. The high fatality rate related to vehicle rollovers clearly indicates the extent of the problem. In Australia's National Road Safety Strategy for the decade 2011-2020, one of the requirements for safer vehicles is the development of a dynamic rollover test protocol. Although the nature of the severe injuries occurring during vehicle rollovers is known, the actual causes are still mostly unknown. In this regard, the Jordan Rollover System (JRS) is a device that could be used to investigate in a testing environment what happens to occupants during a typical vehicle rollover.

This paper describes a modelling effort to simulate vehicle rollover dynamic testing using the JRS. A Finite Element (FE) model that accurately reproduces the geometry and functionality of the JRS testing rig was initially built. The model was then validated against an actual test involving a Sport Utility Vehicle (SUV). The FE model proved to be capable of replicating both the vehicle dynamics and deformation occurring during an actual rollover test with the JRS rig.

The developed FE model will be a valuable tool to investigate different crash scenarios by varying the initial vehicle roll, pitch, yaw angles and roll rate. In particular,

simulations will be able to identify the ability of the rig to replicate crashes under initial conditions derived from real-world rollover crashes, which may be significantly more severe than the test rig has to date been used for.

## Keywords

Vehicle rollover, Jordan Rollover System (JRS), Crashworthiness, Numerical simulations, LS-DYNA.

## Introduction

### Background

Although vehicle rollovers represent only a small percentage of the total road crashes in Australia, they account for a large percentage of the total fatalities. Australian rollover crashes account for: 12% of all Australian road fatalities; around 35% of all occupant fatalities occurring in a single vehicle crash injury event; around 17% of Australian spinal injuries; and are now greater in number than fatalities occurring in frontal or side impact vehicle crashes [6, 16]. The estimated cost of rollover crashes in Australia is around \$3 billion per annum. Similar magnitude of the problem occurs also in the USA and Europe; one in every three occupant lives are lost in vehicle rollover crashes in the USA, whereas in Europe around 10% of road users are killed in such crashes.

To date, the measurement of the roof static strength is the only mandatory rating criterion adopted for assessing the rollover safety performance of new vehicle models. In particular, the quasi-static roof strength testing requirement presently introduced in Australia to address rollover crashes is based on the Insurance Institute for Highway Safety (IIHS) [10] rating system. In order to obtain a five-star rating under the Australian New Car Assessment Program (ANCAP) in the period 2014-2015, a minimum Strength-to-Weight Ratio (SWR) of 2.5 (i.e., marginal) with a single-sided roof crush will be required. The SWR requirement will rise to 3.25 starting from 2016 and, presumably, the intention is to further raise the minimum SWR requirement in following years [1].

So far, no mandatory standard dynamic testing procedure has been defined for assessing the safety performance of vehicles during a rollover event. Australian authorities and consumer groups such as ANCAP have been reluctant to implement any specific rollover dynamic testing procedures until a number of research issues have been resolved. The main issue is whether it is possible to create a dynamic rollover test rig that, in combination with a suitable Anthropomorphic Test Dummy (ATD), can replicate the injury occurring in a rollover crash in a consistent repeatable manner. Such successful combination of a dynamic test rig and ATD could become a powerful tool to help identify the precise causes of severe injuries occurring during vehicle rollovers. An accurate knowledge of rollover injury causes may lead to the development of effective technological countermeasures for mitigating injuries related to rollover crashes.

The Dynamic Rollover Occupant Protection (DROP) project, funded by the Australian Research Council (ARC) in cooperation with industry partners at TARS - UNSW, aims to address the issue of rollover injury causes [7]. In particular, the main goal of the DROP project will be to establish which combination of crash severity, roll kinematics, biomechanical injury criteria, crash test dummy, and restraint systems are capable to address the major proportion of fatalities and serious injuries occurring to seat-belted and restrained occupants involved in rollover crashes.

## Dynamic rollover testing rigs

A review of various rollover crashworthiness tests and dynamic test rigs conducted by [5] indicated the Jordan Rollover System (JRS) as the best candidate to date. The original JRS test rig was designed by the Center for Injury Research (CfIR) [4] as a tool used by forensic engineers to evaluate the potential for occupant injury due to ejection and roof crush as well as the effectiveness of side curtain airbags and seat belts during rollovers [11]. Previous tests conducted with the JRS system have shown a good degree of repeatability [3].

An improved version of the original JRS test rig has been recently developed as part of an Australian Research Council (ARC) LIEF Project grants scheme and the DROP Project, as described by Grzebieta [8]. This improved version of the JRS, which will be referred to as UNSW JRS in the rest of this paper, is a device that could be used in a testing environment to investigate what happens to occupants during a vehicle rollover in a consistently repeatable manner. However, before the UNSW JRS can be implemented into a formal rollover dynamic test protocol, various issues need to be solved. Primarily, it has to be assessed whether this type of rig can replicate the same type and level of injuries occurring in real-world rollover crashes.

In particular, in most rollover crashes the reconstruction of initial conditions is inevitably affected by some level of uncertainty intrinsic in the process of investigation and reconstruction of real-world crash events. As such, in an attempt to replicate the same injury levels in a testing environment it may be necessary to perform multiple tests, each under a different set of potential initial configurations (i.e., initial vehicle velocities angles and rotational rates). Since testing all the potential scenarios of interest would be practically unaffordable, computer simulations represent the only viable method to perform this preliminary sensitivity analysis regarding the effect of uncertain initial rollover conditions. The use of simulations would allow researchers to investigate in great detail what happens during vehicle rollovers, such as the kinematics of occupants and, most importantly, their interaction with vehicle interior. Further, simulations would allow an assessment of the testing rig structural limits under extreme testing conditions, thus preventing any risk to overload the rig.

## Objective and methods

The objective of this research was to simulate vehicle rollover dynamic testing with the UNSW JRS rig. To accomplish this objective, a Finite Element (FE) model that accurately reproduces the geometry and functionality of the UNSW JRS test rig was developed. The model was then validated against the results from an actual crash test involving a Sport Utility Vehicle (SUV).

## Methodology

### JRS rig and test setup with an SUV vehicle

The design of the UNSW JRS rig focused on functionality for research purposes while at the same time ensuring operational flexibility within a regulatory and commercial crash test facility. Figure 1 shows a schematic of the UNSW JRS rig as well as a picture of the actual fully-operational rig that was installed at the Roads and Maritime Services (RMS) CrashLab near Sydney, in New South Wales. The JRS testing attempts to replicate real-world vehicle rollover

events by dropping a spinning vehicle onto an approaching sled that moves at an initially-set velocity. Initial impact conditions can be assigned choosing within a broad range of values. In the case of the UNSW JRS test rig, the roadbed and vehicle roll motions are decoupled, as shown in the schematic of Figure 1. This decoupling allows for flexibility in the operational management of the test rig as well as ease of rig mobility (i.e., the possibility to move and store the rig elsewhere in the laboratory when it is not in use).

The front and rear ends of the tested vehicle are connected to separate arms that are free to rotate and allow the vehicle to drop from an assigned initial height. An initial roll speed is assigned to the hinged vehicle while it drops vertically. Synchronisation between the vehicle roll motion and the translational speed of the approaching roadbed sled is established through calibration runs prior to the actual crash test. It is possible to precisely set the values of the vehicle roll angle and roll rate at which the initial impact has to occur. A constant vehicle yaw angle is set by rotating the entire rig to the desired angle with respect to the direction of motion of the roadbed sled. Also, an initial vehicle pitch angle can be assigned by setting the front and rear ends of the vehicle at appropriate different drop heights.

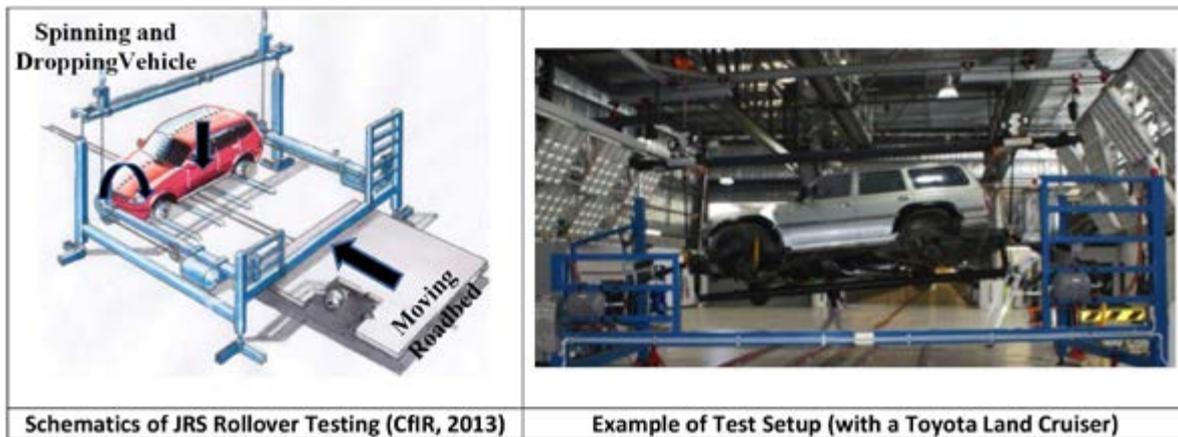
The experimental test setup with the UNSW JRS and a 1994 Toyota Land Cruiser was replicated using the developed computer model. An overview of the test setup is shown in Figure 1 and a summary of the actual initial test conditions is provided in Table 1.

**Table 1: Test with Toyota Land Cruiser – vehicle properties and initial conditions**

Test Vehicle	
Make/Model	1994 Toyota LandCruiser
Mass (including cradle)	2,300 kg
Test Initial Conditions	
Drop Height	117 mm
Vehicle Angles (@ Beginning of Impact)	
Roll	153 deg
Pitch	5.1 deg
Yaw	80 deg
Vehicle Roll Rate (@ Beginning of Impact)	181 deg/sec
Roadbed	
Mass	1,865 kg
Initial Speed (@ Beginning of Impact)	24 km/h

**Computer Modelling**

Vehicle rollover testing with the UNSW JRS rig was simulated using LS-DYNA, which is an FE solver specialised in modelling non-linear transient events such as crashes [9]. The developed JRS model reproduced in detail the geometry of the different components of the actual test rig as well as all the relevant kinematical joints that connect these components together. The appropriate modelling of all the joint connections of the actual test rig was crucial to reproduce all the degrees of freedom allowed to the vehicle during the test. Also, suitable material models were used to characterise the mechanical strength of the various components. As for the vehicle, unfortunately, a model replicating the Toyota Land Cruiser was not available. To overcome this problem, an existing and validated model of



**Figure 1. Schematic of JRS rollover testing rig and example of an actual test setup**

a 2003 Ford Explorer originally developed by the National Crash Analysis Center (NCAC) [13] was used instead. The Explorer vehicle has similar mass and dimensions to the Toyota Land Cruiser used in the actual test, as shown in Table 2. As far as the differences between the experimental test and the simulation could be justified based on the intrinsic variances between the vehicles, the comparison of these results were considered to be a reasonable way to assess the predictive capability of the FE model for this vehicle type. Nevertheless, a future test is planned where the same vehicle type modelled in this paper (i.e., Ford Explorer) will be tested. Moreover, the reliability of the roof deformation predicted by this vehicle model, under both static and dynamic loading conditions, was assessed in previous research studies [12, 14]. Although in the experimental test an Anthropomorphic Test Device (ATD) was placed into the vehicle, the FE model did not include any ATD. At this stage of the project, the focus was to assess the ability to simulate the vehicle kinematics and roof deformation occurring in tests with the JRS rig.

**Table 2: Toyota Land Cruiser and Ford Explorer – mass and dimensions**

	<b>2003 Ford Explorer</b>	<b>Toyota LandCruiser series 80</b>
Weight (kg)	2,240	2,220
Overall length (mm)	4,813	4,970
Max Height (mm)	1,814	1,900
Width (mm)	1,831	1,900

An overview of the modelled JRS rig combined with the Ford Explorer vehicle model is shown in Figure 2. To reduce the computational time required to simulate a complete rollover test, the model replicated the initial conditions at the instant the vehicle started contacting the roadbed. The values of the initial conditions assigned to the model were the same as those measured at the beginning of the impact in the experimental test, which are summarised in Table 1. It was thus possible to avoid simulating the first transitional phase of the test during which the vehicle is accelerated until it reaches the desired roll rate and dropped from the initial vertical height, and the roadbed is accelerated to the desired initial velocity. In particular, the effect of the initial drop height was included in the model by assigning to the vehicle an equivalent initial vertical drop velocity.

The computer model developed during this study would be used to investigate the occupant-vehicle interaction under a variety of different initial rollover conditions. As such, specific adjustments to both the vehicle and the UNSW JRS rig models will need to be made for modelling each of the many desired initial impact scenarios. In order to facilitate the model setup for each different testing scenario,

specific parameters were used to define the relative position of the vehicle and the UNSW JRS rig as well as the initial testing conditions, such as the initial roadbed speed, vehicle rotational rate and vertical velocity, and so on. This parameterisation allows for an automatic adjustment of the developed baseline model to any desired testing scenario by simply assigning the specific values of the initial conditions to the appropriate parameters.

## Results

A comparison of the actual test and the corresponding simulation results is shown in Figure 3. Both the simulated vehicle kinematics and deformation are in good agreement with the experimental test throughout the entire duration of the event. A comparison of the permanent vehicle deformation, which was mostly localised to the roof, front fender and hood, is shown in Figure 4.

A further confirmation of the good agreement between the simulation and the test is provided by the comparison of the curves for the two most relevant physical quantities measured during the test: (a) the vehicle roll rate and (b) the force transferred to the roadbed. Comparisons of the experimental and simulated curves for the vehicle roll rate vs. the roll angle and the time history of the roadbed load are shown in Figures 5 and 6, respectively.

## Discussion

Simulation outcomes confirmed that the developed FE model is capable of reproducing in a reliable manner rollover testing with the UNSW JRS rig and a SUV vehicle. The model simulates in detail both vehicle kinematics and deformation throughout the entire duration of the test. Good and acceptable correlations were found for the vehicle roll rate and roadbed force, respectively.

Although the magnitude of the simulated permanent vehicle roof crush was smaller than what was observed in the experimental test, as indicated by the values of the roof deformation summarised in Table 3, the model was able to reproduce the same failure mode (i.e., buckling of the roof

**Table 3: Roof crush measurements – actual test and simulation**

<b>Target Roof Location</b>		
		
<b>Roof Crush Measurements</b>		
	Test	Simulation
Horizontal component (mm)	220	200
Vertical component (mm)	395	239

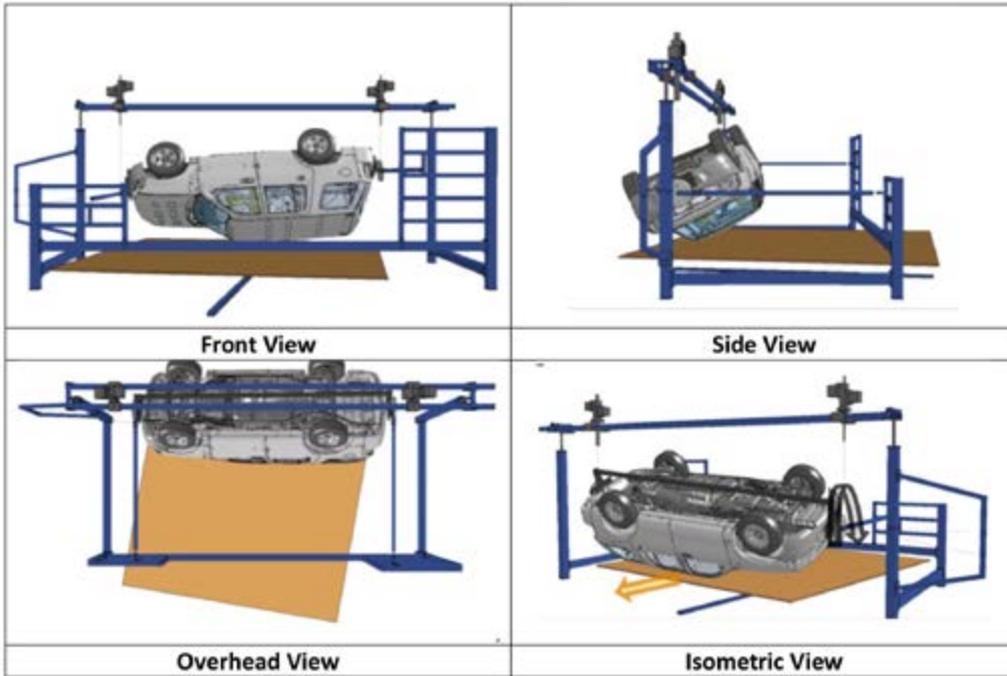


Figure 2. Modelled JRS test setup with Ford Explorer

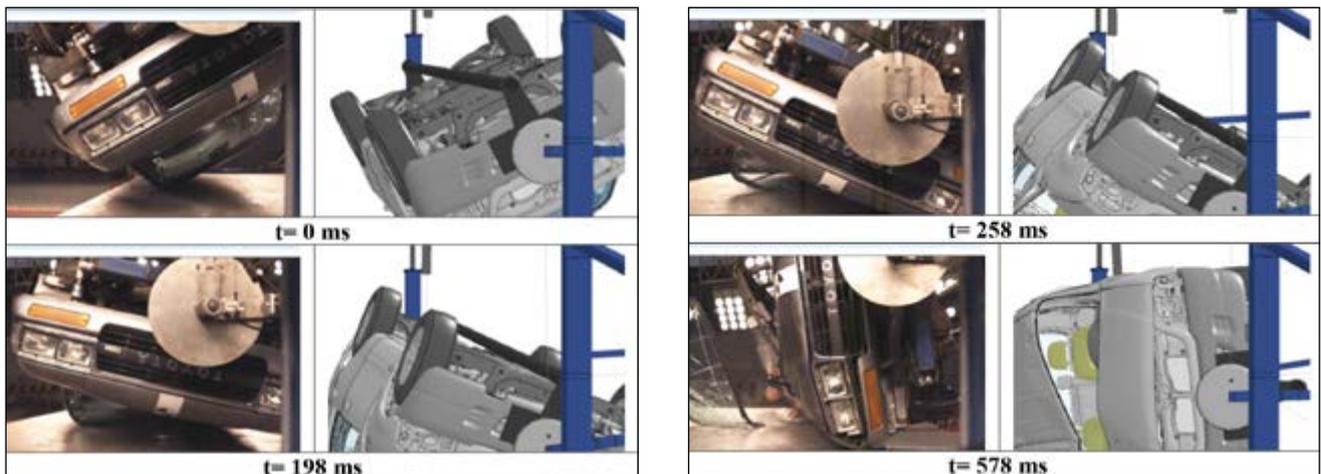


Figure 3. Sequence of test with SUV vehicle - comparison between test (left) and simulation (right)



Figure 4. Vehicle permanent deformation - comparison between experimental test (left) and simulation (right)

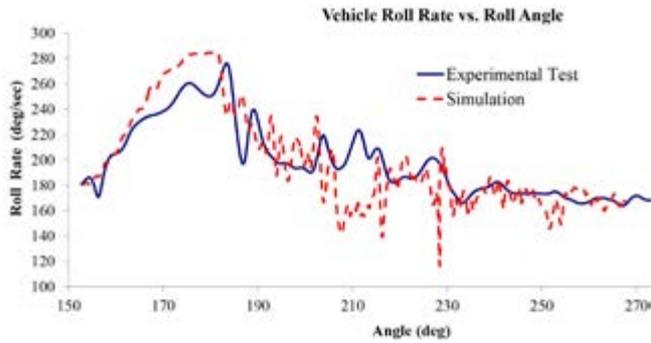


Figure 5. Vehicle roll rate - comparison between experimental test and simulation

with a plastic hinge occurring close to the intersection of the roof and the A-pillar). The smaller magnitude of the simulated roof crush can be likely attributed to a stronger roof of the 2003 Ford Explorer model as compared to the actual tested vehicle (i.e. a 1994 Toyota Land Cruiser). The SWR provides a direct indication of the resistance of the vehicle roof to deform under compressive loading; hence, smaller values of this index imply that a larger magnitude of the vehicle roof crush is expected during a rollover. The actual 2003 Ford Explorer vehicle, which was reproduced in detail in model used for this research, has an SWR of 2.2, as measured according to a FMVSS216 static roof crush test. Although no SWR value was available for the 1994 Toyota Land Cruiser, it is believed that the SWR for this specific version would be in the range of 1.5-1.8, which was a typical performance for SUV's produced during the 1990's.

The vehicle computer model's roof being stronger (SWR = 2.2) than the tested vehicle (SWR  $\approx$  1.5-1.8) ultimately resulted in a higher peak value and a slight phase shift between the experimental and simulated curves of the roadbed load, which are shown in Figure 6. A smaller deformation of the vehicle model's front-right fender during the third quarter of the rollover rotation could have contributed to this phase shift as well.

## Summary and Conclusions

This paper described the development of an FE computer model to be used for simulating in detail the kinematics and deformation of a vehicle during a rollover crash test using the UNSW JRS rig. The main application of this computer model would be that of supporting researchers in assessing whether the UNSW JRS test rig can effectively replicate what happens during real-world rollover crashes, in terms of vehicle kinematics, occupant-vehicle interaction, and occupant injuries.

The reconstructed rollover conditions for real-world crashes are inevitably affected by some level of uncertainty. As such, a thorough assessment of the UNSW JRS rig's capability to replicate typical rollover injury mechanisms

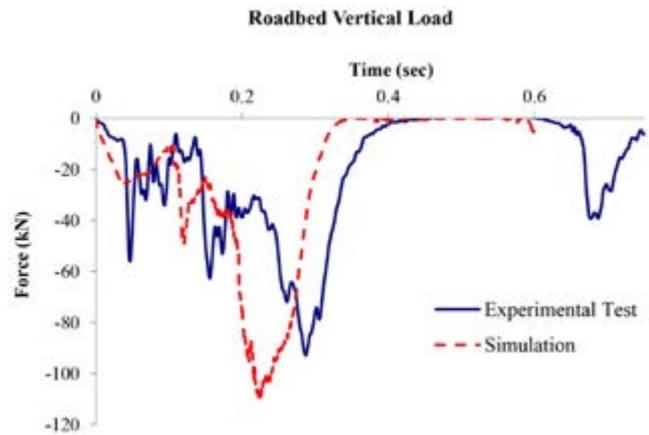


Figure 6. Roadbed vertical load - comparison between experimental test and simulation

would require extensive testing under various initial conditions (i.e., initial vehicle angles, roll rate and drop height). Computer simulations represent a viable method to assess the outcomes of rollover tests using the UNSW JRS rig under the many different scenarios of interest, which would otherwise be impractical to test overall. Once the most representative conditions have been identified from the simulations, then limited experimental testing would be carried out to confirm the simulated results.

A detailed FE model of the UNSW JRS rig was developed and coupled with an existing model of a Ford Explorer. This assembled model was then validated against an experimental rollover test conducted using the actual UNSW JRS rig and a vehicle similar to the modelled Ford Explorer. The developed FE model proved to be capable of reproducing in a reliable manner the vehicle kinematics and deformation during the rollover test. The main differences between the simulation and the actual test were (a) a smaller simulated roof crush and (b) a slight phase shift and peak load of the simulated and experimental roadbed load curves. Both these two differences could be attributed to a stronger roof structure of the modelled vehicle with respect to the actual vehicle used in the test.

A similar modelling effort will be carried out to validate the developed JRS model when coupled with a small passenger car. These validated configurations of the JRS model with the SUV and the car models, in conjunction with already existing validated models of Anthropomorphic Test Devices (ATD), will provide engineers with an affordable way to comprehensively assess the capability of this test rig. In particular, simulations will help researchers to assess whether the UNSW JRS can effectively replicate injuries occurring in real-world rollover crashes. The developed numerical model would eventually represent a useful tool to assist in the investigation of the still-unknown causes of rollover occupant injuries.

## Acknowledgements

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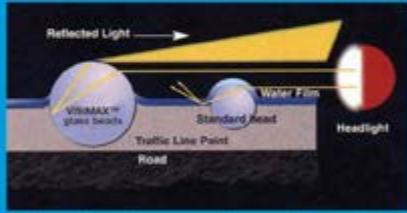
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# Strapped for life or trapped: survey of drivers' knowledge levels and attitudes towards seatbelts and seatbelt law in Zimbabwe

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## Abstract

The study sought to assess drivers' level of knowledge of seatbelts, seatbelt law and attitudes to the seatbelt law using a descriptive survey design. Data were collected from a convenient sample of 180 drivers using a structured interview schedule. The research findings revealed 53.30% correct responses on seatbelt knowledge, 36.94% on seatbelt law and that 47.96% of drivers had negative attitudes towards the law on seatbelts. The findings indicated that there existed some knowledge gaps and that almost 50% of the drivers harboured negative attitudes. The research recommends that the government, using the Traffic Safety Council of Zimbabwe, should increase driver education programmes on seatbelts and seatbelt law following a review of the Defensive Driving Course curriculum. In doing so, this may assist to develop a culture of being 'strapped for life' instead of being 'trapped to death' by ignorance.

## Keywords

Attitudes, Defensive driving course, Knowledge level, Seatbelt

## Background

Road accidents are a major cause of death and injury around the world [1]. In Zimbabwe, close to 2000 deaths and 15,300 injuries result from road accidents annually. Of these deaths, about 1000 are drivers and passengers while pedestrians and cyclists account for the other 1000 fatalities [2].

In order to curb this carnage on the roads, Zimbabwe launched the Decade of Action for Road Safety Campaign on improving road safety in May 2011. This road safety campaign is a clear indication that the government is committed to 'applying brakes' to the careless loss of valuable life, limb and property due to unsafe motoring habits such as the failure to be 'strapped'. It is recorded that seatbelts reduce the risk of death for a front seat car occupant by approximately fifty-percent [3]. Statistics in favour of seatbelts indicate that in America, over 135,000 lives were saved by seat belt use between 1975 and 2000 [4]. By contrast, Zimbabwe is not in the habit of capturing such seatbelt use statistics either due to technological ineptitude or a lack of political will. Positively however,

the country enacted a seatbelt law in 1987 that made it mandatory for all drivers and front seat passengers in Zimbabwe to wear seatbelts while motoring on any road in a light motor-vehicle fitted with seatbelts [5]. This current law recommends the lap and diagonal belt and likewise the law is clear on motorists who are exempted from wearing seatbelts. The seatbelt law also spells out the procedures for seeking exemptions where necessary. Failure to get Ministerial exemption could lead to a fine of twenty dollars for breaching the seatbelt law. The current seatbelt law has now been in force for almost three decades.

This study sought to assess the drivers' level of knowledge of seatbelts and the law; and attitudes towards seatbelt law bearing in mind that the government of Zimbabwe, through the Traffic Safety Council of Zimbabwe (TSCZ), conducts driver improvement training courses called Defensive Driving Courses (DDC), in order to promote road safety. Weekly, an average of 500 drivers attend these courses which are post-licence driving courses aimed at the development and improvement of the drivers' cognitive ability to read and interpret correctly accident causing situations and behaviour [6]. An analysis of the curriculum in [7], shows that it contains the following content areas arranged in Sessions 1 to 8: Preventable or not; How to avoid a collision with the vehicle ahead; How to avoid a collision with the vehicle behind; How to avoid a collision with an oncoming vehicle; How to avoid an intersection collision; Art of passing and being passed; The mystery crash; How to avoid other common types of accidents. Glaringly missing is a session on seatbelts and the law although the goal of the defensive driving course is to bring about a lasting, constructive change in the perceptions and driving conduct of the driver [6].

The Zimbabwe Central Vehicle Registry estimated that in 2012 the vehicle population was 1.3 million compared to 23,256 drivers that had attended defensive driving courses since the country attained independence in 1980. It is apparent that many more drivers are still to attend the country's defensive driving programme. This situation places the TSCZ in a strategic position to play a pivotal role in disseminating seatbelt information to accelerate the 'strapped for life' campaign alluded to in the Decade of Action for Road Safety programme.

## Objectives of the study

The research process was guided by the following objectives:

- to find out how much drivers know about the use of seatbelts ;
- to assess the knowledge of drivers about the seatbelt law; and
- to find out the attitudes of drivers towards the seat belt law.

## Conceptual framework

It is important to situate research in literature so as to clarify key issues of the research and to provide new insights [8]. Similarly, this research focused on analysing seatbelt types and their uses.

### Definition of seatbelts

A seatbelt, which is also called a safety belt, is a safety strap or harness designed to hold a person securely in a seat, as in a motor vehicle or aircraft [9]. The government of Zimbabwe defines a seatbelt as a harness or safety belt assembly that includes both a lap and diagonal strap [5]. In this research, a seatbelt is referred to as a device that can be used to strap oneself in a motor vehicle based on the notion that it is better to be 'strapped for life' than to be 'trapped' to death by ignorance of the value of seatbelts as per the analogy 'strapped' or 'trapped'.

### Types of Seatbelts

There are four basic versions of seatbelts, namely Lap belt; Diagonal belt; Lap and Diagonal belt and the Full Harness [10]. Each of these types has its own strengths and weaknesses. The Lap belt is the simplest type, passing over the lap onto the floor. The wearer is restrained over the pelvis during an impact but the belt does not prevent the upper trunk from moving. The Diagonal belt is a belt that passes in front of the chest from the car roof or side pillar down to the floor. Ideally, this distributes the load over the chest during impact. In practice, the centre of gravity of the body is usually below the line of the belt and in a forward impact; there would be a tendency for the wearer to slide out from under the belt. In overturning accidents, this type of belt would provide little restraint and the head would strike the roof. Then there is the Lap and Diagonal belt that provides restraint in several directions. One of its advantages is that the danger of slipping out under the belt is eliminated [10]. This belt is sometimes referred to as the modern 'inertia reel' type combination. Last but not least, is the Full Harness that consists basically of two belts over the chest and shoulders and one belt over the lap. However, general limitations of this belt are that even in normal use, the 'take-up' buckle used for adjusting the slack can work itself loose and that the buckle can fly open when bumped against in an accident.

In Zimbabwe, vehicles should be fitted with safety belts of the lap and diagonal belt type [5].

### Uses of seatbelts

In general, all the four types of seatbelts are known to prevent death and injury. However, the lap and diagonal type is considered to be the most basic but most effective type of seatbelt that can be used to get motorists 'strapped'

for life. The basis of the argument is that when used properly, research has shown that lap and diagonal belts reduce the risk of fatal injury to front-seat passenger car occupants by 45% and the risk of moderate-to-severe injury by 50% [3]. In general, injuries sustained when one is not wearing a seatbelt can be up to five times greater. This can be explained as follows: firstly when a car's sudden stop or turn is caused by a collision with an external object such as another car, this produces what is called the 'first collision'. Inertia then causes the driver's body to continue the car's motion until this body collides with objects inside the car such as the steering wheel, the dashboard or windscreen. It is this sudden and violent motion of the body that results in the 'second collision'. Then a 'third collision' occurs when the internal organs of the crash victim's body hit against the chest wall or skeletal structure [1]. The purpose of the seatbelt becomes that of minimising the effects of the 'second collision' which subsequently leads to the avoidance of the 'third collision' by providing something for the body to hit, which in this case is the seatbelt. The seatbelt then absorbs the shock of sudden deceleration and spreads the force of collision over the body parts that can easily take it. The collision that, ironically, is with the seatbelt, allows the occupant to ride down the accident so that the driver and vehicle obtain zero velocity at the same time. Admittedly, this can only happen to one who is 'strapped' to the car seat!

The proper use of seatbelts also ensures greater control of one's vehicle at sudden stops; control on quick turns; control under unexpected hazards and can act as a reminder to the driver that accidents can happen even to the most careful driver at the lowest of speeds. Also, therefore, there is need to minimise economic losses due to road accidents. These economic costs include wage losses, medical expenses, administration costs, property damage and employer costs; not forgetting the decline in quality of life to accident victims and their families [11].

As such, driver education on the benefits of being 'strapped' informs motorists of the consequences of their actions in the pre-crash phase.

## Methodology

This study used a descriptive survey approach on the advice of [12] and [13], that the approach is suitable for investigating phenomenon such as knowledge levels and attitudes. The afore-mentioned authors argue that a well-planned and conducted survey enables a researcher to collect accurate information on what the situation is at the time of the research. A survey looks with intense accuracy at the phenomena of the moment and then describes precisely what the researcher sees [14]. Information for use in establishing the drivers' level of knowledge and attitudes was collected using a short structured interview schedule. The interviews were conducted at four large shopping

locations in Harare, namely: Hatfield, Machipisa, Sam Levy and Marimba. The locations were conveniently chosen to be representative of Harare residents as per the four cardinal points of the compass, namely; Eastlea in the east, Hatfield in the south, Machipisa in the west and Sam Levy in the north. The survey candidates were selected conveniently as the researcher went from one available driver to the next over a period of four weeks. Each driver responded to a short structured interview schedule that lasted approximately six minutes. A total of forty-five (45) drivers were interviewed at each of these four shopping centres. The data that were collected were quantified and presented using tables that depicted the number of responses and percentages. Data pertaining to each research objective were treated separately in order to clearly show the extent of fulfilment of each of the research objectives.

## Presentation of data and discussion

### Objective one: to find out how much drivers know about the use of seatbelts

The responses to the level of knowledge on seatbelts were first tabled in a cluster to show the general level of knowledge of the respondents. The responses to each statement were then discussed separately.

**Table 1: Level of seatbelt knowledge** N=180

Statement	Frequency and percentage of correct responses	Frequency and percentage incorrect responses	Totals
Main function of seatbelts	109 (60.55%)	71 (39.45%)	180 (100%)
It is safer to be ejected in a car crash	82 (45.56%)	98 (54.44%)	180 (100%)
It is safer to be belted up even when the car catches fire	83 (46.11%)	97 (53.89%)	180 (100%)
Seatbelts should be worn all the time	108 (60.00%)	72 (40.00%)	180 (100%)

**On the question of the main function of seatbelts:** the majority of respondents knew the main function of seat belts since 109 (60.55%) drivers stated correctly that the main function of seat belts was to prevent the 'second' collision which is the major cause of injury and death when the body collides with objects in the vehicle such as the steering column. By contrast, 71 (39.45%) drivers were ignorant on the issue.

**On the question of whether or not it is safer to be ejected when a crash occurs:** A total of 82 (45.56%) drivers knew about the benefits of ‘being strapped’ in the car. By contrast, 98 (54.44%) drivers perceived that they would be ‘trapped’ and as such they would rather be thrown out of a crash vehicle. In most cases, wearing a seat belt prevents ejection from the vehicle [4]. As justification, [4] draws attention to the National Highway Traffic Safety Administration (NHTSA) statistics of 2006 which showed that 75 percent of drivers ejected during car accidents were killed in America. Regrettably, this type of data for Zimbabwe was not available to this study.

It was important to check the consistency and reliability of responses by asking the respondents to indicate their degree of knowledge regarding the need to wear seatbelts in specific cases of extremely bad car crashes.

**On the question of whether or not it was safer to have been belted up than not, even in a car accident that would result in a car catching fire or being submerged in water:** The responses revealed that 83 drivers (46.11%) remained firm on being ‘strapped’ although earlier on, 109 drivers (60.55%) had indicated that they knew the main use of seatbelts. This apparent objection can be attributed to myths about seatbelts. Myths or misgivings arise from a lack of concrete and convincing information on an issue or facts [15], such as on the benefits of seatbelts. Some drivers felt that they would be ‘trapped’ in the car thereby effectively minimising any chances of escaping, whereas research shows that a driver who is wearing a seatbelt has a better chance of escaping death than a driver who is not ‘strapped’ even in a fire or water incident. When an accident is so bad that a vehicle catches fire, an unbelted driver is likely to be killed instantly whereas the one who is ‘strapped’ might be rescued, injured but still alive [16]. A total of 97 or 53.9% of survey candidates thought it was dangerous to use a seatbelt in those circumstances.

**On the question of whether or not to wear seatbelts every time:** As many as 108 drivers (60%) were inclined to wear seatbelts often. The other 72 drivers (40%) gave reasons such as: ‘seatbelts are not necessary for low speeds; seatbelts are not for slow rural speeds; pregnant women need not be compelled to wear seatbelts; reversing should be exempted’.

The overall picture shown in Table 1 is that the average of the correct responses was 53.30% and this means that there is a seatbelt knowledge gap on the part of nearly half of drivers in Zimbabwe.

**Objective 2: to assess the knowledge of drivers about seat belt law**

**Table 2: Level of knowledge on seatbelt law N=180**

Statement	Frequency and percentage of correct responses	Frequency and percentage of incorrect responses	Totals
The legal seatbelt type for light motor vehicles	75 (41.67%)	105 (58.33%)	180 (100%)
Persons who are required to wear seatbelts by law	88 (48.89)	92 (51.11%)	180 (100%)
Persons and situations legally exempted from wearing seatbelts	49 (27.22%)	131 (72.78%)	180 (100%)
Maximum fine for not wearing a seatbelt	54 (30.00%)	126 (70.00%)	180 (100%)

**On the question of the legal type of seatbelts for light motor vehicles:** Only 75 drivers (46.67%) correctly identified the lap and diagonal type as opposed to 105 drivers (58.33%) who answered incorrectly. The implications are that drivers could install the ‘wrong’ type of seatbelts that is not mandated when replacing worn seatbelts. The lap and diagonal type has been found to reduce the risk of fatal injury to front seat motorists and is deemed to be the safest and most commonly used in cars, vans, minibuses, trucks and the driver’s seat of buses and coaches [1].

**On the question of persons who are required to wear seatbelts by the law:** Eighty-eight (88) drivers, who represent 48.89% of the sample, responded correctly that it is mandatory in Zimbabwe for drivers and front seat passengers to be ‘strapped’. Ninety-two drivers (51.11%) answered incorrectly displaying ignorance of this aspect of the road safety law.

**On the question of legal exemptions:** There were 49 drivers (27.22%) who correctly identified reversing situations and pregnant women as examples of situations and persons that were exempted by the seatbelt law. As many as 131 drivers (72.78%) gave incorrect responses, which is evidence of a low level of knowledge among most drivers. This implies that some drivers had to suffer the discomfort of seatbelts in ignorance such as when one is pregnant. However, it is important to note that modern

retractable lap/sash belts are not uncomfortable and the woman and baby are much safer if she wears a belt.

**On the question of the legal maximum fine for not wearing seatbelts:** As many as 126 drivers (70%) of the respondents answered incorrectly as compared to 54 drivers (30% of the respondents) who stated correctly that the maximum fine is twenty United States Dollars (\$20). Ignorance of such law could render motorists vulnerable to corrupt elements among law enforcement agents who could extort more amounts of money than is stipulated. The irony of it is that whereas the penalty for a heinous offence such as rape is publicly known to be a minimum of eight years behind bars in a maximum security prison, the schedule of fines for the breach of traffic fines appears to be difficult to obtain. The researcher failed in his attempts to get the relevant document from the authorities and copies were unavailable for sale. The overall picture shown in Table 2 is that, on average the correct responses amounted to 36.94% indicating that there is a vast need for seatbelt knowledge among the respondents.

### Objective 3: To find out the attitudes of drivers towards seatbelt law

**On the question of attitudes towards the mandatory wearing of seatbelts:** A total of 123 drivers (68.34%) stated that they were in favour of the seat belt law while 48 drivers (26.66%) were not. Those in favour of the law supported their position with reasons such as that seatbelts were useful in saving lives, with some drivers even testifying that they had survived road crashes because they heeded the seatbelt law and were ‘strapped’.

Some of the drivers who expressed negative attitudes towards the seatbelt law cited the discomfort of seatbelts to pregnant women, thereby again exposing their ignorance about seatbelt wearing exemptions, as was shown earlier in Table 2. There were other respondents who perceived that seatbelts can be a hazard and that they would rather be thrown out of crash vehicles. These responses further served to reinforce the correlation between low levels of

knowledge and subsequent negative attitudes indicative of feeling trapped in the analogy ‘strapped’ or ‘trapped’.

**Attitude to paying a fine for not wearing a seatbelt:** Positive attitudes were recorded from 97 drivers (53.89%) while 71 drivers (39.44%) expressed negative attitudes about paying a fine for not wearing a seatbelt. The positive attitudes were supported with reasons such as: ‘seatbelts save lives; a fine is a reminder and a lesson not to do it again; if you break the law you pay.’ Negative attitudes were supported by reasons such as: ‘seatbelts are a risk to drivers if a vehicle catches fire or falls into a dam; there is no need to be fined when you are reversing; police should just caution the driver; after all seatbelts are unnecessary; the fines vary so we do not know the correct amount to pay’.

The findings showed the existence of knowledge gaps among some drivers that underscores the need for adult education to engage drivers in a process to change and promote a culture of being ‘strapped’. It is encouraging to learn that in America seat belt use is on the rise due to laws, education and technology. There has been an increase in seat belt use from 11% in 1981 to nearly 85% in 2010, saving hundreds of thousands of lives [17].

**Attitude towards applying to the Minister of Transport for exemption from wearing a seatbelt:** One hundred and one drivers (61.67%) disagreed with this section of the seatbelt law while 61 drivers (33.89%) agreed with the procedure; with eight drivers (4.44%) taking a neutral stand. The majority of the respondents cited the bureaucratic nature of the process that rendered it long and ineffective, especially in cases of emergency such as one involving the ferrying of a pregnant woman in a pickup truck. There were also those who stated that it was unnecessary for the Minister to be directly involved in matters of operations which the traffic police could directly and effectively handle at road blocks by conducting on-the-spot visual assessments and interviews. Those in favour of this procedure were of the attitude that they trusted the law-makers who had made the law in the first place.

**Table 3: Attitude to seatbelt law** N=180

Statement	Strongly agree	Agree	Neutral	Disagree	Strongly disagree	Total
Attitude to making the wearing of seat belts mandatory	104 (57.78%)	19 (10.56%)	9 (5.00%)	38 (21.11%)	10 (5.55%)	180 (100%)
Attitude to having to pay a fine for not wearing a seat belt	38 (21.11%)	59 (32.78%)	12 (6.67%)	36 (20.00%)	35 (19.44%)	180 (100%)
Attitude towards applying to Minister of Transport for exemption from wearing a seat belt	44 (24.44%)	17 (9.45%)	8 (4.44%)	23 (12.78%)	88 (48.89%)	180 (100%)

Indications were that either there were insufficient consultations with all the stakeholders before the enactment of this law or that the dissemination of the information was flawed, thereby creating this need for driver education.

## Summary

Using a survey method and a short structured interview schedule that was administered on a convenient sample of 180 drivers in Harare, the study discovered that on average the Zimbabwean drivers possessed less knowledge on seatbelts (53.30%) than is available in books, journals and on the internet. When asked about information pertaining to seatbelt law that is contained in S.I. 247 of 1987 of the Road Traffic (Safety belt) Regulations, their general level of knowledge on the seatbelt law amounted to 36.94%. The study further established that almost half of the drivers had negative attitudes towards the seatbelt law. The DDC Instructors Guide that was last revised in 1979 has a narrow coverage of seatbelt content and is totally deficient of seatbelt law information.

## Recommendations

The study recommends that the Zimbabwe government, through the Traffic Safety Council, should rewrite its DDC curriculum in order to improve the nature and form of seatbelt and seatbelt law information to increase drivers' knowledge and promote attitude change. Since a curriculum is not static, [18] argue that it must encapsulate the dynamic needs of individuals and those of the society, such as the learning and safety needs of Zimbabwe's drivers. Accordingly, the research recommends the inclusion of a session on seatbelts with the following sub-topics: History of Seatbelts; Seatbelt Use and Benefit; Seatbelt Facts versus Myths; The Road Traffic Safety Belt Regulations; and Community Mobilisation for 'Strapped for Life' Campaigns. The research also recommends that law-makers, road safety experts and adult educators should engage drivers in a consultative process since adults, by nature, need to participate in matters that affect them [19]. The researcher also recommends research in other related road safety education areas such as the legalisation and promotion of child restraints; and improved seatbelt law enforcement.

## Conclusion

Based on these findings, the study concludes that some knowledge gaps exist with drivers regarding information on seatbelts and seatbelt law. In addition, many drivers hold negative attitudes towards the seatbelt law. The driver improvement programme's curriculum needs to improve in both content and scope. The Traffic Safety Council of Zimbabwe should champion initiatives to educate drivers and inform motorists on seatbelt and seatbelt law thereby

promoting a culture of being 'strapped' for life.

The research also underscores the incompatibility of education initiatives and effective law enforcement for improved seatbelt usage. There is sufficient evidence to show that laws, education and technology have led to incredibly high user rates - 85 to 95% in some countries - thereby saving hundreds of thousands of lives [20]. Zimbabwe as a country and the Southern Africa Development Community (SADC) as a region can best learn from these success stories.

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# Contributed articles

## Reducing Rear-end Crashes with Cooperative Systems

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### Abstract

This paper presents an evaluation of the effectiveness of a cooperative Intelligent Transport System (C-ITS) to reduce rear-end crashes. Two complementary simulation techniques are used to demonstrate the benefits of the C-ITS. Traffic (VEINS) and sensor (SiVIC) simulations use realistic data related to traffic and roads in Brisbane's Pacific Motorway; driver's reaction time; and injury severity to evaluate benefits. The results of our simulations show that C-ITS could reduce rear-end crash risk by providing several seconds of additional warning to drivers.

### Keywords

Rear-end crashes, Cooperative ITS, Traffic simulation.

### Introduction

Rear-end collisions represent approximately one-third of all reported crashes in Queensland and often result in injuries which have long-standing consequences [1]. These crashes constitute the third most common type recorded by police. Between 2000 and 2009, rear-end crashes cost the Queensland community \$1.7 billion. Rear-end crashes often arise from a complex set of interacting factors including the roadway, environment (such as poor weather conditions), vehicle capability and road user factors [2].

Rear-end crashes are over-represented on roads with higher speed limits (70-90 km/h) [3]. Signalised intersections are

also rear-end crash-prone areas due to the variability in drivers' braking behaviours during the signal change. Post-crash analyses have shown that inattention and distraction, from in-car and external sources, and a deterioration of driver alertness are associated with an increased risk of involvement in rear-end collisions [1, 4, 5]. Unsafe following distances have been identified as a contributing factor in between 10% and 66% [2] of rear-end crashes.

Several engineering, education and enforcement approaches have been used to curb rear-end related crashes. There are a plethora of ITS in-vehicle technologies such as Forward Collision Warning (FCW), which provide warning to the driver and performs emergency braking on behalf of the driver when a crash is imminent [1]. However the use of Cooperative-ITS (C-ITS) to prevent rear-end crashes have not been comprehensively evaluated. Most of the studies do not take into account human factors issues (e.g. reaction time) and limitation of wireless network reliability. Furthermore there is a lack of naturalistic on-road benefit assessment mainly due to limited market penetration of such devices. In this paper, we use relevant variables such as real traffic network (Brisbane Highway), real traffic data and driver's reaction time, in a traffic simulator (VEINS), to assess the benefits of cooperative systems.

### C-ITS intervention assessment: general methodology

We use simulation to evaluate the safety benefits of C-ITS. Simulation is chosen over on-road experimentations

because the latter are time-consuming and require considerable resources. Simulation has its limits, but a well-designed simulation framework that integrates models of the road environment; virtual sensors and telecommunication devices; and vehicle dynamics, can be a good approximation to evaluate the performance of C-ITS applications. Empirical evaluation is not entirely removed from this process, as several of the models used in our simulation are based upon empirical data.

## Two levels of simulation

Our approach is focused on simulation with two levels of abstraction. The first level of abstraction is microscopic simulation related to individual vehicle. The simulator we are using is the SiVIC-RTMaps™ framework as described in [6]. SiVIC was designed to support a limited number of vehicles (typically less than 10) and cannot simulate large traffic. The second level of abstraction allows us to simulate interaction between a large number of vehicles. It is a microscopic traffic simulation, linked to a wireless network simulator. We used the VEINS [7] framework that combines the open-source SUMO traffic simulator with the OMNet++ network simulator. The two approaches are complementary, as they allow for testing of the same scenario from different level of abstraction, namely individual vehicles, and vehicle’s fleets.

## Scenario

Our investigation focuses on a common scenario applied in both simulation scales. It features a string of vehicles driving on a freeway. At some point, the string’s leader brakes suddenly because of an incident, which can trigger a series of rear-end crashes or near misses downstream. This scenario has several advantages:

- It focuses on rear-end crashes, which are a significant road safety problem as explained in the introduction.
- It focuses on freeways, which is a simple driving environment with few parameters to control in a simulation.
- It allows testing different approaches to FCW including non-cooperative and cooperative ones such as EEBL (Electronic Emergency Brake Lights).

## Rear-end crash risk index

To assess the performance of C-ITS intervention, we use a crash risk metric based on the Time to Collision (TTC) and Intervehicular Time (IVT). Risk is a combination of the probability for an event to happen and its associated severity. The instantaneous crash risk is thus the probability of crash multiplied by the expected severity.

The crash probability can be computed from the TTC and IVT separately [8], as those two values express different

driving conditions. The severity is obtained using the Equivalent Energy Speed (EES) [9] (see Eq. 4 below). The EES gives an indication of the kinetic energy that was dissipated by the collision. The EES value is then linked to probability of injuries experienced by the vehicle’s occupant(s), based on the Maximum Abbreviated Injury Scale [10].

Let us have a string of  $n$  vehicles:  $\{V_1, \dots, V_n\}$ . We define several risk indicators. For a pair of vehicles  $i$  and  $j$ , there is  $R_{j,i}$  (Eq. 1) that expresses the risk of collision between those two vehicles, as measured by vehicle  $i$ .  $R_{j,i} \in [0,1]$ . If the risk equals 1, the crash is inevitable or has already happened. Depending on the information available to each individual vehicle, we may have  $R_{i,j} \neq R_{j,i}$ .

$$R_{j,i} = R_{j,i,TTC} + R_{j,i,IVT} \quad (1)$$

$$R_{j,i,TTC} = P_{j,i,TTC} \times g(V_j, V_i) \quad (2)$$

$$R_{j,i,IVT} = P_{j,i,IVT} \times \max \left( g(V_j, V_i), g(V_j, V_i - \gamma TTC_{i,j}) \right) \quad (3)$$

with:

$$P_{j,i,TTC} = f(TTC_{j,i}) \quad (4)$$

$$P_{j,i,IVT} = f(IVT_{j,i}) \quad (5)$$

$$g(V_j, V_i) = G(EES_{j,i}) \quad (6)$$

$$EES_{j,i} = (V_i - V_j) \frac{2m_i}{m_i + m_j} \quad (7)$$

where  $P_{j,i,TTC}$  (Eq. 4) and  $P_{j,i,IVT}$  (Eq. 5) are the probabilities of crash as computed from the relevant TTC, resp. IVT;  $g(V_j, V_i)$  (Eq. 6) represents the severity of a hypothetical crash where the two involved vehicles do not change their current speeds;  $g(V_j, V_i - \gamma TTC_{i,j})$  represents the severity of the crash that would happen if vehicle  $i$  was to perform a sudden emergency braking manoeuvre with deceleration  $\gamma$ . The severity is based upon the likelihood  $G$  of severe injury or death, depending on the crash’s EES. Eq. 7 gives the EES, with  $V$  and  $m$  the vehicles’ speeds and masses.

A vehicle equipped with multiple sensors or C-ITS communications thus has an array of risks associated with each of the vehicles it can detect:  $\{R_{1,i}, \dots, R_{n,i}\}$ . From there, we can create a global risk value  $R_{g,i}$ , which is defined as the global collision risk as perceived by a single vehicle  $i$ . This value becomes relevant when a vehicle has access to multiple sources of information. Importantly, another vehicle nearby might not have access to the same information. The value of  $R_{g,i}$  for each vehicle will thus change depending on their situation and what they know about the overall driving context gathered from communicating vehicles. Eq. 8 shows how we compute  $R_{g,i}$ .

$$R_{g,i} = \max \left( R_{1,i}, \dots, R_{n,i} \right) \quad (8)$$

If all vehicles share their individually perceived risk of the driving situation we can then create an augmented collision risk called  $R_{aug}$  (Eq. 9).  $R_{aug}$  is the combined risk for the whole driving context.  $R_{aug}$  is most informative if its scope is limited; indeed, if there is a single dangerous event in a string of 1,000 vehicles,  $R_{aug}$  will only return a very small increase in the total risk.

$$R_{aug} = \frac{1}{n} \sum_{j=1}^n R_{g,j} \quad (9)$$

Concretely,  $R_{aug}$  is a risk estimation (gathered from communicating vehicles) which will be greater than the local risk  $R_{j,i}$  if a crash occurs among communicating vehicles. The knowledge of the overall risk  $R_{aug}$  will give extra time to drivers to react. Our approach is similar but simpler than the average-based risk valued computed in [11], as we do not weigh the risk values received from other vehicles.

## From few vehicles to a large fleet

### Previous SiVIC simulation result using 5 vehicles

Our previous research [6] implemented the vehicles' string scenario in SiVIC with a five vehicles platoon. We recorded the local and global risks for the last vehicles of the string and then compared each risk indicator; the goal was to show whether using a C-ITS application increases the drivers' awareness of the risk. To compare both approaches, we defined a crash risk threshold of 0.4. A risk higher than the threshold would require the driver to take evasive actions otherwise the vehicle would crash.

At first, we measured the local risk ( $R_{j,i}$ ) with a non-cooperative ITS system. The local risk could warn drivers on average five seconds before they potentially collide with the vehicle in front. However, this system gave them no information on the crash risk associated with the original emergency braking occurring several vehicles in front of them.

**Table 1: Variations of  $dt$  over six runs**

Event begins at... (s)	$t_A$	$t_{L,5}$	$dt$
47.29	51.94	58.85	6.91
57.27	60.55	67.82	7.27
50.0	53.52	59.86	6.34
97.45	101.05	108.28	7.23
96.77	99.93	107.2	7.27
379.85	383.05	390.66	7.61

Accordingly, we investigated the performance of a C-ITS system. We used  $dt$  as our main metric, where  $dt = t_{L,i} - t_A$ .  $t_{L,i}$  is the time when the local risk ( $R_{j,i}$ ) passes the threshold

for vehicle  $i$ , and  $t_A$  is the time when  $R_{aug}$  does the same. In all of the simulated runs,  $R_{aug}$  passed the threshold well before  $R_{4,5}$ , and shortly before  $R_{3,4}$  which means that vehicles four and five have extra time to prepare for emergency actions. Table 1 shows the values obtained for six simulated runs compared to  $t_{L,5}$  only. On average, vehicle five has  $\overline{dt} = 7.1$  seconds extra time to react when it uses C-ITS.

## Rationale for using VEINS

In the previous findings, the simulated C-ITS system showed it had the potential, for a given vehicle, to give on average seven seconds of additional warning time compared to a purely local system. Overall,  $R_{aug}$  signalled the danger three to four seconds after the initial emergency braking. This suggests that apart from the few vehicles immediately following the leader, the other vehicles in string would benefit from this system by having more time to prepare. Drivers would be alerted, slow down or engage in evasive manoeuvre, limiting the scope of the incident.

However, since we were not able to simulate more than five vehicles in SiVIC we were not able to verify whether that the benefit holds at larger scale. Additionally, an intervention that is positive in the first few vehicles might have unforeseen consequences when considering the larger string. For example, in [12] the immediate braking created additional lower severity crashes when vehicles were not all equipped with the system. This highlights the needs for larger scale simulation. In the remainder, we will do so using VEINS. However, one should note that traffic simulation is not the most appropriate medium for simulating safety-related ITS applications. Indeed, vehicle's behaviour is controlled by car-following models that rarely allow for a crash to happen. In our case, by using the risk we can still study safety C-ITS application; indeed, the risk derives from the TTC and IVT. SUMO's car-following model will still allow for plausible TTC and IVT values.

## Methodology

In this new study, we implemented a 45km long section of Brisbane's Pacific Motorway in SUMO (Fig. 1). The section covers both driving directions from the Coronation Drive exit in the CBD to Ormeau, including all entry and exit ramps, interchanges and some neighbouring large roads. All lanes are accurately represented.

Instead of five vehicles, we consider a much larger number of vehicles corresponding to the actual traffic flow on the Pacific motorway. We inject into SUMO the traffic volumes recorded by induction loops along that portion of the network. The simulation runs for two minutes with a traffic volume equivalent to the one measured at 7am. About 2,500 vehicles are injected on the road. One minute into the scenario we trigger an incident by having a randomly

selected vehicle (the leader) brake suddenly. Many variables are recorded during the run, but we will only need a limited subset to estimate risks:

- Position (X,Y)
- Speed
- Acceleration
- ID of the vehicle in front
- Following distance

VEINS pre-existing functions simulate the complete WAVE stack; we selected the two-ray interference propagation model as it is more realistic compared to a simple free-space propagation model and fits well with our own previous research [13]. Most of the work was centred on implementing the functions necessary for playing the emergency scenario and the C-ITS application.

## Results

We run the scenario as described in the previous section and extract the risks, specifically the estimated augmented risk  $R_{aug}$  and the local risks  $R_{j,i}$ . We define a danger threshold of 0.4, when the risk has reached a value high enough to

warrant intervention by the driver or an ITS system. We select this value based on the specific methodological limitations of VEINS, compared to SiVIC.

In Fig. 2, we show the evolution of the risks depending on the number of vehicles considered when computing  $R_{aug}$ . Indeed, the number of vehicles considered when computing  $R_{aug}$  will influence its value. In our simulation, despite the heavy traffic injected into the highway, there were only about a dozen vehicles within a 500 metres (on the same lane) radius around the incident (crashing vehicle). Thus, we show  $R_{aug}$  computed with three, four and five vehicles (plus the leader). The ‘A’ curve is  $R_{aug}$ , while the other curves represent the local risk estimated by each vehicle in the vicinity:  $R_{1,2}$  is ‘D’,  $R_{2,3}$  is ‘B’,  $R_{3,4}$  is ‘C’,  $R_{4,5}$  is ‘E’, and  $R_{5,6}$  is ‘F’. The horizontal line is the risk threshold previously defined.

Table 2 summarises the results extracted from those curves in terms of extra time gained by using  $R_{aug}$  to warn the drivers instead of just their local  $R_{j,i}$ . Those results are in line with our previous findings in SiVIC, which shown no benefits for the first couple of vehicles (Vehicles 2 and 3 never benefit from  $R_{aug}$ ), but increasing benefits further upstream. However, if too many vehicles are taken into account when computing  $R_{aug}$ , the useful additional warning time does not realise ( $R_{aug}$  remains under the threshold, not warning drivers). It is important to note that without crashes in VEINS, we can never have  $R=1$ .

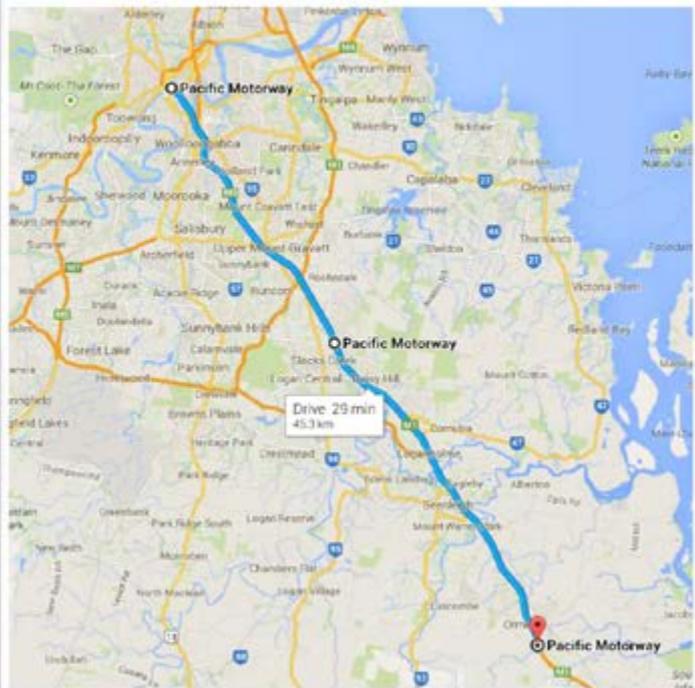
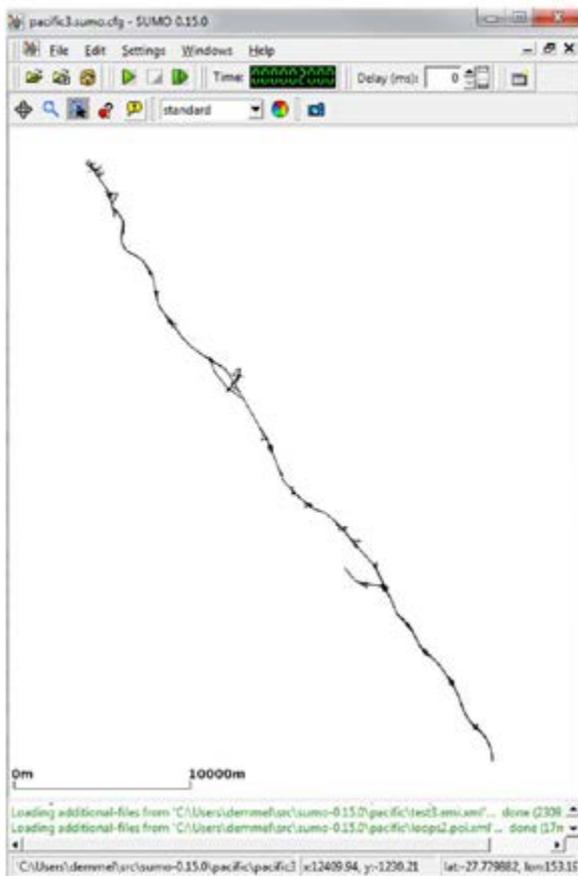


Figure 1. Map of the SUMO scenario (left) and its location in Brisbane

Otherwise, this would have allowed  $R_{aug}$  to rise higher whenever the first crash took place.

In Fig. 3 we force the second vehicle ('D' curve) to crash six seconds after the initial event. We can see that  $R_{aug}$  immediately reflects this increased danger (a crash *did* happen) for the whole group, and crosses the threshold at 6.3 seconds into the event. As a result, the following vehicles benefit from additional warnings of 0.7, 3.1, and 6.4 seconds, respectively for vehicles 4, 5 and 6 (also shown in Table 2). This scenario is perfectly in line with our previous results in SiVIC. Compared with the benefits seen in Table 2's second-to-last row, one can see how  $R_{aug}$  is useful to describe the total risk of the driving situation, especially if a very risky event has already happened such as a crash or a near-miss.

### Conclusion

This paper used simulation techniques to demonstrate the safety benefits of C-ITS on a motorway. Our simulation scenario consists of generating a crash and observing how following vehicles react to crash risks and avoid pileups with and without C-ITS. We used realistic data such as traffic flow and road geometry of the Pacific Motorway. The crash risk estimation is based on solid theories. We showed that the use of C-ITS to transmit crash risk (warning), gathered from communicating vehicles, before a driver could actually perceive it locally, gives drivers extra time to react and mitigate multi-car pileups. C-ITS is a disruptive technology and there is a need to understand the effects of introducing such technology on human factor issues.

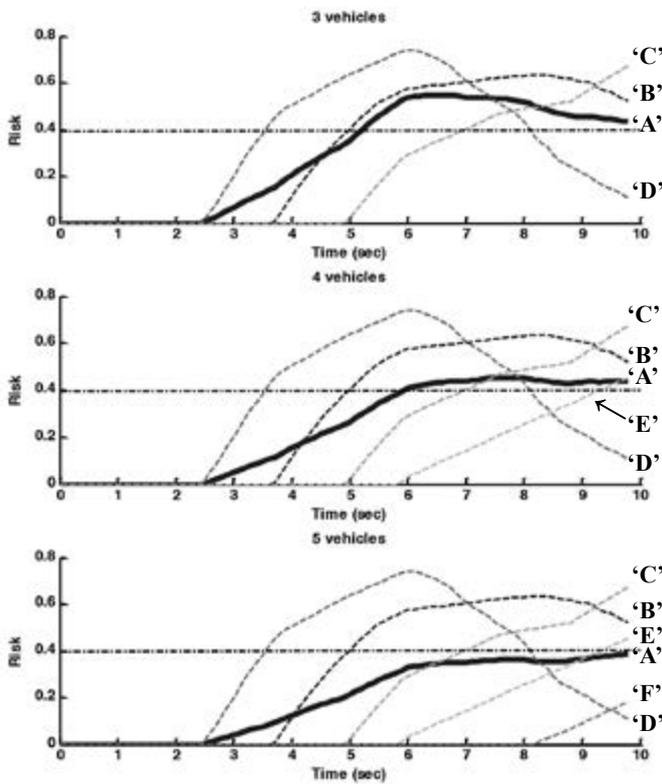


Figure 2. Augmented and local risks for 3, 4 and 5 vehicles (plus leader) following the leader  
 –  $R_{aug}$  is the 'A' curve

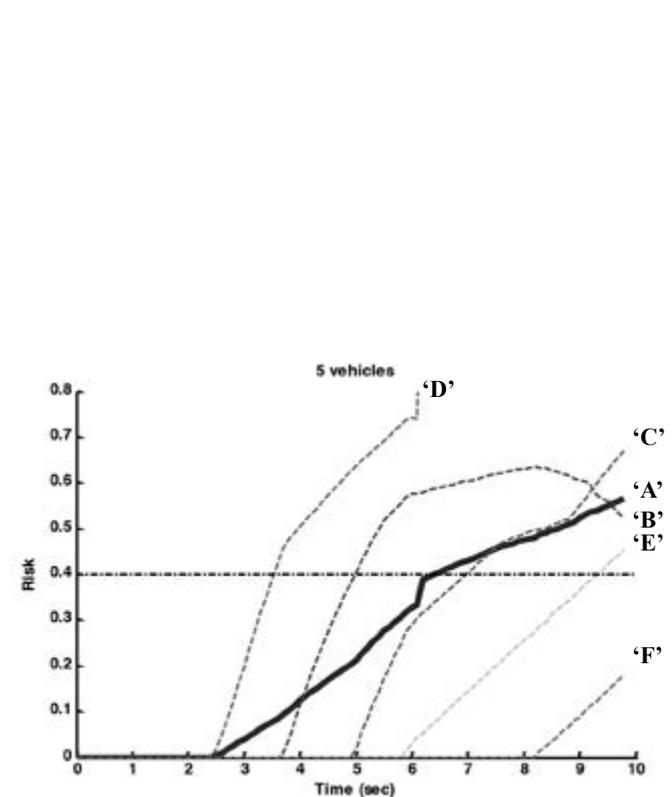


Figure 3. Risks for five vehicles with vehicle two forced to crash

Table 2: Additional warning time offered by C-ITS over local sensors for each vehicles

Number of vehicles accounted in $R_{aug}$	$R_{aug}$ passes threshold at... (s)	Benefit for vehicle 2 (s)	Benefit for vehicle 3 (s)	Benefit for vehicle 4 (s)	Benefit for vehicle 5 (s)	Benefit for vehicle 6 (s)
3	5.2	None	None	+1.7		
4	6.0	None	None	+1.0	+3.3	
5	10.0	None	None	None	None	+2.7
5 + crash	6.3	None	None	+0.7	+3.1	+6.4

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# Autonomous emergency braking – the next seat belt?

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## Introduction

Autonomous Emergency Braking or AEB is a safety technology which monitors the traffic conditions ahead and automatically brakes the car if the driver fails to respond to an emergency situation. It is one of the most significant developments in vehicle safety since the advent of the seat belt or the airbag. As technology improves, the numbers of fatal and serious injuries on UK roads are reducing. With improved vehicle structures, improvements to the road infrastructure and consumer test programmes such as Euro NAP, the number of fatalities has continued to fall, from over 7,000 in the 1970s to just 1,754 in 2012 in the UK alone [1].

However, some types of injury have been proportionally increasing in recent years - in particular injuries to vulnerable road users and pedestrians. We have also seen a significant rise in whiplash and associated personal injury

claims. Auto braking technologies, such as AEB, can help to reduce the kind of incidents that result in these significant injuries by preventing the crash from happening at all.

Some of the reduction in casualties we have seen on UK roads is due to improvements in commonly recognised safety systems, such as seat belts and airbags; defined as passive safety systems that aim to prevent or reduce injury in a crash. However, AEB can be defined as an active safety system, operating before the crash happens and aiming to prevent the crash from occurring in the first place, or to reduce its severity. With the increasing technological complexity and computing power accessible from a modern vehicle's control systems, the availability and performance of these active safety systems are improving rapidly. Human error accounts for 90% of crashes, so it is easy to understand how driver intervention systems can help to substantially reduce the likelihood of a crash.

## AEB: on the roads

Electronic Stability Control (ESC) was one of the first highly effective crash avoidance technologies. This system, which became widespread in new vehicles from 2000, helps to prevent loss of control or skidding during high speed manoeuvres or on slippery surfaces and is therefore very effective at preventing or mitigating single vehicle crashes. A subsequent report from the Department for Transport showed that ESC reduces the risk of your involvement in a life threatening crash by up to 25% [2].

ESC was an important enabling technology for AEB, since it automatically controls the vehicle's brakes. AEB builds on this by using forward looking sensors to anticipate potential hazards ahead. The first AEB systems used RADAR technology and were often associated with Adaptive Cruise Control (ACC) and Forward Collision Warning (FCW) systems. These were most often optional systems, sometimes fitted at high cost, but were shown to have a significant benefit, reducing damage and injuries by at least 10% and 14% respectively [3].

Mainstream AEB entered the market in 2008 when Volvo launched standard fit City Safety, using a low cost laser based LIDAR sensor. As it was fitted as standard the effect could be easily statistically measured and subsequent international insurance claims data rapidly highlighted the benefits. This showed a reduction in third party damage crashes and injuries by at least 15% and 18% respectively [4]. Thatcham's study of UK insurance claims data showed an 18% reduction in third party personal injury claims and a 9% reduction in third party damage claims over the period from 2009 to 2013.

The evidence that AEB is working on our roads is extremely encouraging, not least because it is already contributing to reducing the whiplash problem for the UK. There are over 550,000 whiplash claims annually in the UK, costing society £2 billion and adding an extra £90 a year to the average motor insurance premium [5, 6].

Such is the benefit from AEB systems that through the vehicle Group Rating process, UK insurers have already adjusted the insurance rating on cars fitted with the system. The aim is to encourage wider awareness and demand for AEB and since 2012 vehicles with standard fit AEB systems and which have passed a few basic operational criteria, have seen a reduction in their vehicle grouping, translating into potential savings of around 10% on consumers' insurance premiums. The performance of the system is assessed by Thatcham using a dynamic test against a stationary realistic car target, at speeds from 10-50km/h; the performance is used to derive the size of the group rating reduction applied.

This pioneering system to encourage broader AEB fitment has subsequently been adopted in Germany too, giving

more incentives for manufacturers to fit AEB systems and protect even more road users.

## AEB: system types

Different AEB systems are effective at different speed ranges, depending on the sensor technology used. Three quarters of all collisions occur at speeds of less than 20mph [7]. The majority of these low speed crashes are seen in city environments such as queuing traffic, at junctions or roundabouts; where most whiplash injuries also occur. This is where AEB systems using the cost effective LIDAR sensor are very effective, typically avoiding crashes completely at speeds of up to 12-15mph and mitigating those up to 25mph.

Higher speed crashes can be addressed by RADAR based systems, which are typically more expensive and often only available currently as optional extras depending on the vehicle manufacturer. These 'Urban' type crashes are not as common, but as you might expect are normally more serious. RADAR based systems are effective at preventing or mitigating these higher speed crashes – up to motorway speeds.

As environmental, economic and congestion pressures encourage more cyclists and pedestrians, we have seen the proportions of injured road users changing. Whilst overall numbers of all casualties are decreasing each year, pedestrians and particularly cyclists now represent an increasing share of the injuries. In 2012 in the UK there were 420 pedestrian and 118 cyclist fatalities [8]. AEB can now address these vulnerable road user collisions too, since systems are now combining cameras with radars in sensor fusion.

## AEB: assessments

Thatcham is a member of Euro NCAP and has been leading the implementation of testing procedures into their consumer vehicle safety ratings programme. Tests are carried out to exacting standards with the vehicles precisely controlled by test engineers and robots, using high precision measuring equipment. This work involved the use of real world crash scenarios to define the tests, bringing about the development of a realistic car target that could be repeatedly impacted, and the subsequent definition of the assessment and scoring procedures.

For Euro NCAP the tests mirror those implemented by the aforementioned UK insurance group rating process and these low speed tests against a stationary car target are termed 'City' tests. Thatcham and Euro NCAP have also defined higher speed tests against both stationary and moving car targets, known as 'Inter-Urban' tests.

From 2014 these city and inter-urban tests have become a key element of Euro NCAP's new car assessment programme, see: [www.euroncap.com/results/aeb.aspx](http://www.euroncap.com/results/aeb.aspx)

Similarly detailed test procedures for the assessment of pedestrian AEB systems are almost complete and are planned for implementation during 2016. This type of test procedure is now also being adopted further afield in the US, Japan and China.

### ADAS: the future

ESC and AEB are just the beginning of the revolution in crash avoidance. Advanced Driver Assistance Systems (ADAS), such as AEB, designed to prevent or mitigate different crash types, are entering the market every year. The future will bring autonomous steering to prevent head-on collisions and ‘run off road’ crashes which are often very serious, or even fatal. As technology develops, we’ll also see opportunities to reduce other vulnerable road user deaths such as the junction scenario where a car pulls out in front of a motorcycle.

It is important for drivers to remember that most of the ADAS systems currently available are designed to support them only in emergencies and that the driver remains responsible for the vehicle at all times. In the longer term, we can expect to see systems that will automate normal driving functions in limited traffic circumstances, such as control of speed and steering on motorways, in order to relieve the driver of the driving burden. Eventually, driverless cars will transfer this burden from the driver to the vehicle – but that is a long way off for the mainstream market, with the first fully driverless cars not expected until the end of the next decade.

The new world of crash avoidance technologies is on our roads today in the form of AEB, and is already reducing crashes, preventing injuries and fatalities and saving associated societal costs.

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## Motorcycle safety through smart technology

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Spend a Sunday meandering your way along the Great Ocean road or through many of the other winding roads, all over Australia and you are sure to encounter dozens of motorcyclists gliding around the smooth curves. The freedom of controlling a machine through the bends accelerating and braking, shifting their weight, picking the best line and leaning into the corners makes a scenic ride even more enjoyable. However with the highs of motorcycle riding come significant risks, many of which can be reduced through intelligent selection of the bike’s safety features.

Per kilometre travelled, motorcycle riders are over 37 times more likely than car drivers to be seriously injured when on the road [1]. Motorcycles account for 4.5% of all Australian passenger vehicle registrations and 1.1% of vehicle

kilometres travelled. However, motorcycle riders and pillion account for approximately 15% of all road crash deaths and an even higher proportion of serious injuries.

Of the 287 people killed on Victoria’s roads in 2011, 49 were riders of motorcycles. This represents 17% of the road toll [2]. The Motorcycle Council of NSW states that almost half (48%) of crashes in their 2006-2010 study involved excessive speed [3]. Importantly this does not mean they were all exceeding the speed limit, just that their speed was inappropriate for the conditions. In fact many accidents occur due to poor road surface, other road users’ errors or even animals and debris on the road.

A small change in balance or direction when rounding a corner, loose stones or the need to brake suddenly can all

lead to loss of control accidents. A motorcycle ABS (Anti-lock Braking System) enables a rider the necessary time to focus on steering and balance while braking as hard as they can to wash off some of the speed. In an emergency a rider has many factors to consider: looking forward and to each side to select an ‘exit’ path; steering to avoid the immediate hazard; balance of the bike and rider; and braking pressure both on the front and rear wheels. Here the motorcycle ABS systems are most helpful. Sensors on each wheel use tiny magnetic impulses to detect the exact wheel speed and its rate of change. These signals are transmitted to the ABS control unit in a less than 1/100th of a second. The ABS computer is programmed with the bike’s specific characteristics, tyre size and even calliper elasticity. Almost instantaneously the ABS unit compares the front and rear wheel speeds, throttle position and other elements of the bike’s status and relieves the pressure by tiny increments to allow the wheel to maintain its deceleration but stay on the safe side of the slip threshold.

The advanced versions of ABS systems also perform brake proportioning. A rider squeezes the front lever to control the front brake and uses the foot lever to control the rear. A highly skilled rider can control this front and rear pressure and expertly balance both in normal riding conditions. However, in an emergency the advanced versions of ABS can modulate the braking proportionally to allow the rider to rapidly reduce speed without worrying about locking a wheel and losing control. Some of these advanced systems also have the ability to detect if the rear wheel is lifting and modulate the brake force to make sure the wheels stay in touch with the road.

In September 2013 the world’s first motorcycle stability control system was launched on the KTM 1190 Adventure. Bosch’s Motorcycle Stability Control (MSC) uses an inertia sensor module which computes the vehicle’s lean and pitch angles more than 100 times per second. By analysing the lean sensor data, the difference in speed between front and rear wheels, as well as other motorcycle-specific parameters such as tyre size, tyre shape and sensor location, the ABS control unit calculates the physical limits of brake force on the basis of lean angle.

If the MSC recognises that a wheel is starting to lock, the ABS control unit activates the pressure modulator in the hydraulic brake circuit. This lowers and then restores the brake pressure within a fraction of a second, with the result that the perfect amount of brake pressure is applied as is necessary to keep each wheel from locking. (To see this in action follow the video link at <http://www.youtube.com/watch?v=mO6-Y40V59U>).

Technology has advanced so rapidly in the last decade that purchasers of new bikes are reliant on the motorcycle associations, journalists and technology experts to keep the industry up to date. It is critical that riders choosing

their next motorcycle seek out the latest information on these safety technologies. The modern ABS systems are so small and well-tuned that the rider doesn’t even notice them. There are many systems available that have multiple settings allowing the rider to select from several calibrations best suited to their riding environment. ‘Wet’ setting softens the interventions to ensure optimal braking on slippery roads, ‘Race’ setting allows track day riding without compromising braking safety. Many enduro or dirt bikes allow the ABS system to be switched off thereby maintaining the ability to lock up rear wheels on dirt track adventures but reactivate the safety feature for the ride home.

The developing world has millions of two wheelers on their roads. With 90% of road fatalities vulnerable road users – including cyclists, pedestrians and motorcyclists - many of these are the family income-earner. These families often cannot afford to own a car so the small sub-125cc motorcycle is a popular transport choice. With the smallest Bosch ABS unit weighing less than 700g there is no need for manufacturers to limit these safety systems to larger bikes on the grounds of weight or cost. Last year Bosch sold its one millionth Motorcycle ABS unit and its current generation ABS9 unit is 1/2 the size and weight of its predecessor.

The German accident statistics database GIDAS shows that one-quarter of all motorcycle accidents could be prevented if ABS were standard. The severity of a further one-third of these accidents could be mitigated by the antilock braking system. A recent study in USA [4] states, “Over-braking and under-braking have been shown to be common factors in motorcycle crashes. The rate of fatal motorcycle crashes per 10,000 registered vehicle years was 37% lower for ABS models than for their non-ABS versions.” The study concludes “ABS appears to be highly effective in preventing fatal motorcycle crashes.”

Australian states and territories all have motorcycle safety high on their priority list. The Victorian police have recommended ABS be considered as part of an ANCAP safety star rating system. The TAC in Victoria is running a campaign called ‘The Perfect Ride’ which addresses key safety issues including; speed, road position and awareness of other road users. In Western Australia the Office of Road Safety follows a similar line encouraging motorcyclists to wear the appropriate safety gear, and importantly, choose the right bike. Queensland’s Department of Transport urged riders to understand their own heightened vulnerability and act accordingly to minimise the risk of collision.

The European Parliament has mandated ABS from 2017 for all motorcycles with more than 125 cc displacement. This directive applies from 2016 to any new models that are launched. Smaller motorcycles with a displacement of 50 cc or more must be fitted either with ABS or a combined

braking system. In the USA the influence of European bikes means that ABS will soon be available on most models. The American Motorcycle Association “doesn’t oppose ABS, but has always maintained that ABS should be a rider’s choice, must be affordable and riders must be able to switch ABS on and off on dual-sport machines.” It is a clear, world-wide movement to ensure reliable, proven safety systems are introduced as quickly as possible to all levels of motorcycles to help slow the disturbing rise in fatal and serious accidents.

While Australia has some of the world’s best conditions for riding we also have a disproportionate level of death and serious injury. With an increasing number of motorcycles sharing the ever more crowded roads it is critical that riders give themselves the best chance of avoiding an accident

regardless of who is the cause. A bike that can avoid wheel lock up and be controlled while braking hard is a valuable asset in ensuring that any ride finishes on a high; not on a hospital trolley.

## Notes

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# Standards and consumer information – the winning formula for vehicle safety in the UN Decade of Action

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Each year 1.3 million people are killed and up to 50 million injured in road crashes worldwide. By 2030 the World Health Organisation (WHO) forecasts that road crashes will become the fifth leading cause of death rising to 2.4 million per year [1]. To try to avoid an inexorable rise in road injury the United Nations has proclaimed a Decade of Action for Road Safety 2011-2020 [2] with the goal to reduce the forecast level of fatalities in 2020 by 50% avoiding five million deaths and 50 million injuries. To support this aim the UN Road Safety Collaboration (UNRSC) [3] has prepared a Global Plan for the Decade based on the “safe system” approach; an integrated and holistic strategy that simultaneously promotes safer vehicles, safer roads and safer road users [4].

The world’s vehicle fleet reached 1 billion in 2010 and is forecast to double in a decade. This unprecedented increase is occurring in developing countries which account for

90% of global road deaths. About 48% of all road fatalities are vehicle occupants. So unless action is taken now to improve vehicle safety, the newly motorising countries will suffer a growing road injury burden. Today passenger cars in Australia, Europe, Japan and the USA are much safer than ever before. This is the result of regulatory “push” and market “pull”. Mandated standards, combined with consumer demand, have stimulated the production of safer vehicles by the automobile industry. The challenge now is to promote similar progress in the rapidly motorising countries.

Through the UN World Forum for Harmonisation of Vehicle Regulation (WP29) [5] motor vehicles can now be internationally approved without further tests provided they meet the relevant UN standards. The World Forum uses two Agreements, adopted in 1958 and 1998, to provide a legal framework that allows any UN Member State to apply voluntarily a wide range of motor vehicle standards. The UN Forum’s most important safety regulations are: seat belt anchorages - Reg. 14; safety belts and restraint systems - Reg. 16; occupant protection in frontal collision - Reg. 94; occupant protection in lateral collision - Reg. 95; electronic stability control - GTR 8; and pedestrian protection - GTR 9.

Unfortunately these standards are not yet universally applied. For example of the record level of 65 million new passenger cars built last year as much as one third would fail to pass the front and side crash tests. So there is much work to be done to promote global harmonisation during the Decade of Action.

In parallel to regulatory action over the last thirty years a major effort has been made to increase the public demand for safer motor vehicles. This has mainly involved consumer information to stimulate car buyer's awareness of safety through New Car Assessment Programmes (NCAPs). The first NCAP was created in 1978 by the US National Highway Traffic Safety Administration (NHTSA). This was followed by the creation of Australasian NCAP in 1993, Japan NCAP in 1995 and European NCAP in 1997. There are now nine NCAPs or similar bodies active in Asia, Australia, Europe, Latin America and the USA [6].

NCAPs help to create a 'market for safety' by simultaneously raising awareness of the car-buyers and providing an incentive to manufacturers to build safer cars. They usually rate cars by awarding stars based on occupant protection scores. These are derived from the measurement of the loadings and decelerations that occur to instrumented dummies during the crash. Front and side impact tests are the most important occupant protection assessment tools used in legislation and by NCAPs.

The UN's frontal impact test (UN Reg. 94) simulates a car to car crash in which at 56 kph the vehicle hits a barrier that replicates the soft front end of the other vehicle. The impact is 'offset' with a 40% overlap as many frontal crashes occur like this. Most NCAP tests use 64 kph (the speed at which fatalities are most common). The side impact test (UN Reg. 95) uses a trolley that hits the vehicle just above the door sill area at 50 kph. Some NCAPs also include additional pole, whiplash and pedestrian impact tests.

NCAPs have been highly successful in promoting safety. For example, in 1997, one year before the EU's mandatory front impact test at 56 kph, Euro NCAP released its first tests at 64kph. Despite the increased stringency, manufacturers rapidly saw the benefits of achieving high scores in Euro NCAP. As a result most new cars in the EU now achieve five stars; a safety level that far exceeds the original 1998 regulations. Indeed a five star Euro NCAP car has a 36% lower fatality risk than a car that only meets the regulations. Over the last ten years over 100,000 deaths in the EU have been avoided and probably 40% of this progress is attributable to safer vehicles.

An area of growing importance both to regulators and NCAPs are crash avoidance systems. The benefits of crash protection are obvious but it is even better to avoid the crash in the first place. To achieve this positive effect the automotive industry has invested heavily in developing technologies that will assist the driver from having a crash at all. The earliest such system was Anti-Lock Brakes (ABS) and this has been followed more recently by

Electronic Stability Control (ESC) which has proved to be a highly effective crash avoidance system.

ESC prevents loss of control (under-steer or over-steer) skidding incidents and is widely acknowledged to be the most important safety device since the seat belt. It works by detecting if the steering inputs of the driver are inconsistent with the vehicle's direction of travel. If this happens ESC applies the brake to one of the wheels using the ABS to correct the slide. Since 2012 ESC is mandatory in new cars in Australia, Europe, and the USA. It is estimated that it will avoid 10,000 deaths annually in the USA and at least 4,000 in the EU. The UN adopted a global standard for ESC in 2008 and increasingly ESC is being included as a required technology in NCAP ratings.

In 2011 the Global New Car Assessment Programme (Global NCAP) was launched to provide a platform for cooperation for NCAPs around the world to share best practice and exchange information [7]. A charity registered in the United Kingdom, Global NCAP is governed by a Board of Trustees and held its inaugural Annual Meeting of Global NCAP in Melaka, Malaysia in May 2012. All nine active NCAPs worldwide attended, making the event the largest ever gathering of its kind.

Global NCAP receives grant support from the FIA Foundation, the Road Safety Fund, International Consumer Research and Testing, the World Bank Global Road Safety and other philanthropic sources. In turn Global NCAP is providing financial and technical support to new NCAP pilot programmes in Latin America and in Asia. Global NCAP works closely with its Associate Member NCAPs (such as ANCAP and Euro NCAP) around the world sharing best practice and inter-NCAP co-operation.

The annual road fatality rate in Latin America is 17 deaths per 100,000 individuals. This is almost double the average rate registered for high income countries where the average is 10 deaths per 100,000. It is projected that by 2020 the rate in the region will reach 24 deaths per 100,000.[8] Since 2010, however, the Latin New Car Assessment Programme (Latin NCAP) has become a major stimulus for passenger car safety,[9] having tested over forty models. Its first results revealed levels of safety in top selling cars twenty years behind North America and Europe. However, last year five models were awarded five star ratings which shows remarkable progress and demonstrates positive engagement by the car manufacturers. As a result of the success of the pilot programme Latin NCAP is becoming a legal entity in 2014 with continuing support from Global NCAP, and also the Inter-American Development Bank.

The ten countries of the ASEAN region [10] are already experiencing the negative safety impacts of rapid motorisation with high fatality rates similar to Latin America. ASEAN's vehicle sales are forecast to increase from 2.4 million in 2011 to 4.7 million units by 2018 which potentially makes the region the world's sixth largest

automotive market [11]. Given the expected doubling in sales improved vehicle safety can play an important part in ASEAN countries plans for the Decade. So in 2011, Global NCAP, ANCAP, and Euro NCAP partnered with the Malaysian Institute of Road Safety Research (MIROS) to launch the ASEAN New Car Assessment Program (ASEAN NCAP).

Last year ASEAN NCAP released the first two phases of crash tests of 18 vehicles manufactured in the key markets of Malaysia, Thailand and Indonesia [12]. The results highlight the wide variation in vehicle safety, with star ratings ranging from two to five stars. ASEAN NCAP has already achieved some early success. In their Phase 1 test, where Proton received a one-star rating for its single airbag Saga FLX compact car, the company stopped production and replaced it with the FLX+ model with dual airbags [13]. In its latest Phase 3 tests ASEAN NCAP will make a side impact test a pre-requisite for a four or five-star rating and also hopes to encourage carmakers to make ABS standard and ESC available for consumers.

More recently Global NCAP has launched a ‘Safer Cars for India’ which tested five popular models to assess their performance in both the UN Reg. 94 crash test at 56 kph and at an NCAP speed of 64 kph. The results were launched at a Conference [14] held in New Delhi in January. All but one of the five models failed the Reg. 94 test and scored zero stars at 64 kph as a result either of poor body shell strength or lack of air bags. Encouragingly, VW decided to make airbags standard in their Polo and with this extra equipment the car’s performance jumped from zero to four stars. The crash tests received extensive media coverage and will hopefully act as a catalyst to the development of an NCAP in India.

In a helpful endorsement of the work being undertaken by Global NCAP the UN has recognised the beneficial effects of NCAPs. In September 2011 Mr Ban-ki Moon, UN Secretary General, submitted a recommendation [15] to the UN General Assembly stating that NCAP’s “have proved to be very effective in creating a market that encourages consumers to choose vehicles based on their safety ratings” and encouraging Member States to “participate in the new car assessment programmes in order to foster availability of consumer information about the safety performance of motor vehicles.” This recommendation was endorsed by the UN General Assembly in a resolution adopted in April 2012.

Given the growth of vehicle fleets and road injury, improved automobile safety is rightly a key component of the Decade’s Global Plan. If the twin track approach of regulatory push and demand pull is applied, there is no reason why vehicle related road casualties cannot be significantly reduced by 2020. That is why it is so important that rapidly motorising regions apply the most important regulations offered by the UN World Forum and that also NCAP’s continue promoting five star ratings. This will be the winning formula for automotive safety in the Decade of Action.

## Notes

1. See [http://who.int/violence\\_injury\\_prevention/road\\_safety\\_status/2013/report/en/](http://who.int/violence_injury_prevention/road_safety_status/2013/report/en/)
2. UN General Assembly Resolution 64/255, March 2, 2010.
3. The UNRSC brings together the WHO, the UN Regional Commissions, the development banks, some governments and civil society representatives in a consultative body that promotes best practice in road injury prevention.
4. See [http://www.who.int/roadsafety/decade\\_of\\_action/plan/global\\_plan\\_decade.pdf](http://www.who.int/roadsafety/decade_of_action/plan/global_plan_decade.pdf)
5. Visit the Forum (also known as Working Party 29 of the UN Economic Commission for Europe) at: <http://www.unece.org/trans/main/welcwp29.htm>
6. ASEAN NCAP, Australasian NCAP, China NCAP, European NCAP, Japan NCAP, Korean NCAP, Latin NCAP, US NCAP and the Insurance Institute for Highway Safety.
7. For further information visit: [www.globalncap.org](http://www.globalncap.org).
8. See - Road Safety Strategy – IDB, Closing the Gap: Reducing road traffic deaths in Latin America and the Caribbean, Action Plan 2010-2015 page 3.
9. See - <http://www.latinncap.com/en/?pg=&id=>.
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# Car safety for tomorrow

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## Introduction

The safety of cars has improved exponentially over the last 20 years, but can this level of improvement continue at this rapid pace?

- What are the cars for tomorrow?
- What will the next 20 years bring in terms of safety?
- Will there be a 'road toll' at all?
- Will there still be a place for crash testing?

Physical crash testing has played a major role in the improvement in the crashworthiness of cars. Well-designed structures are vital in protecting occupants. Coupled with sophisticated restraint systems, in the main cars are much safer than they have ever been. While new physical crash tests and new crash test dummies are in the pipeline, it is highly evolved technologies that have become the main focus.

There are many issues and questions that arise from what has been the rapid introduction of safety assist technology<sup>1</sup> (SAT). Crash test organisations around the world are faced

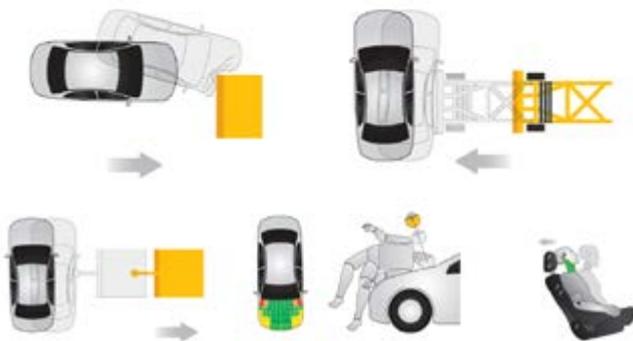


Figure 1. The range of ANCAP current testing

with considerable challenges in terms of determining the relative safety value of these SATs. Physical crash testing continues apace but SAT assessment is looming as a higher priority.

Certainly, some SATs are showing signs of excellent opportunities to reduce road trauma. Further, some companies have already indicated that they will have market-ready autonomous cars available from 2020. While it will take some time for the best SATs to become ubiquitous - and it may take just as long for consumers to relinquish 'control' of their cars - potential new players in the automobile market and tech-savvy generations may well result in some surprises.

## Physical crash tests

The Australasian New Car Assessment Program (ANCAP) has been undertaking crash testing for more than 20 years. In this time, and in particular in the last decade, there has been huge improvement in the performance of car structures. During the first decade of testing it was common for cars across the spectrum of brands to perform poorly.

The reason for ANCAP's establishment was due, in part, to apparent differences in the level of safety of cars sold in the USA. Indeed it was not uncommon for cars that appeared to be the same, to perform quite differently in terms of safety when tested in different jurisdictions.

Over time, crash testing around the world has improved and the most commonly used current suite of tests is very demanding. In ANCAP's case the current tests include:

- 40% Frontal Offset test at 64km/h
- Side Impact test at 50km/h
- 90° Side Pole test at 29km/h
- Pedestrian tests (adult and child) at 40km/h
- Whiplash tests (static and dynamic)

In the early days, in terms of illustrating the relative performance of a car structure, these tests, particularly the 40% Frontal Offset test, provided deplorable results. A simple observation clearly highlighted the difference between good or bad and perhaps life or death.

Over time, improved structures led to better results and, together with airbags and improved seat belts, the risk of death or serious injury started to fall. In more recent years we have seen continued improvement in structures and even

<sup>1</sup> SAT in this article generally refers to active safety devices/systems (e.g. Autonomous Emergency Braking, Lane Departure Warning with active steering, cross traffic alerts and the like)

more sophisticated restraint systems which include seat belt pretensioners, load limiters, additional airbags and the like.

The issue now becomes whether the passive safety features of cars are about as good as they will ever be. At first blush it might be considered that there is always room for improvement. At the same time one might question whether these features need to be better. On balance, there are still many opportunities for improvement in the car itself but the increase of SAT may shift that balance over time.

With many more cars today performing well in crash testing, it is no longer possible to infer the broad level of performance in a test as it may have been a decade or more ago simply by seeing the aftermath of the test. Today, a whole range of less obvious active safety technology plays a vital role in determining the relative safety of a car.

Passive safety, which dominated the ratings assessment for many years, while still critical, is beginning to play second fiddle to active safety. In other words, if a car can avoid or mitigate a crash then there is the prospect, hypothetically, that passive safety may become less of a priority.

## Safety assist technology

As little as five years ago it was unlikely that the rapid development and introduction of SAT could have been foreseen. Earlier technology like anti-locking braking systems (ABS) had been in cars for many years before it truly became a valuable SAT. To some extent, the same applied to electronic stability control (ESC). These days ESC and ABS are ubiquitous and their safety benefits well known. The length of time it took for these two technologies to become mainstream, which was substantial, was a poor indicator of what might be ahead.

Today, the adoption of new technology in cars has never been higher. Manufacturers now bring SATs to market more quickly than in the past. While many of these SATs are only offered as optional extras, increasingly they are becoming standard – largely through the impact of NCAPs.

For its part, ANCAP demonstrated the benefits of non-regulatory programs when it made ESC mandatory for a five star safety rating from January 2008. It is only just recently that regulation has now followed. Therein lies the benefit of ANCAP working with government to usher in life-saving changes to cars.

Autonomous emergency braking (AEB) has emerged with very strong potential for saving lives. Some have suggested that it may be up with the seat belt in terms of its impact on road trauma. Certainly initial research is showing very promising results. NCAP organisations around the world are now bringing AEB into their rating systems. For example, Euro NCAP began assessing AEB this year and although not yet a mandatory requirement for a five star

rating, it is a very important part of the assessment process. So important, that it is very difficult to achieve a five star safety rating without AEB. [2] Another excellent example of a non-regulatory program at work.

Other safety assist technologies including blind spot monitoring, cross traffic alerts, lane departure warning systems, adaptive headlights, telematics, forward collision warnings, adaptive cruise control and the like are becoming more common in the cars of today. [3]

Even more advanced than these SATs will include, for example, vehicle-to-vehicle (V2V) communication, heavy traffic pilots, autonomous rear collision avoidance, vehicle-to-infrastructure communication (V2I), car platooning and ultimately, autonomous cars.

Much has been said and written about autonomous cars and it can sometimes be difficult to distinguish between fantasy and reality. However in very recent times there have been pivotal announcements from major manufacturers about their autonomous cars.

Nissan, Toyota, Honda, Ford, GM and others have stated that increasingly, from 2020, autonomous cars will be on the market. But what does this mean? Will the cars really be autonomous in the sense that you may be able to summon your car from the garage to your door and then have it drive you to your destination? [4]

Perhaps.

More likely, there will be incremental change and improvements in automated technology that will see an increasing number of activities in the car being surrendered by drivers. At some point along a continuum of advanced technology and structural development, the car will effectively be autonomous. We may not even realise the enormity and significance of the changes over time. We will just accept them as the norm.

Different manufacturers will move along the continuum at different paces and with different technology. New players may well enter the market and manufacture and supply cars using new and more flexible methods – with high technology the key to their products. Apple and Google are just two technology companies in this space. [5]

What we will see from this technology will be significant and lasting reductions in road trauma. While it will take many years for the SATs to filter through the car parc, safety benefits should start accruing quickly with crash, death and injury rates falling.

Gerhard Steiger, President of the Bosch Chassis Systems Control Division Lithuania put it this way:

*“Fully autonomous driving will come about one step at a time,” Steiger says. At first, driving on highways with*

*an ever greater degree of automation and at ever higher speeds will be possible, until the highway pilot can take over the entire trip. Two major challenges remain. First, inner-city driving, since automated vehicle functions have to deal with dense traffic involving a large number of road users traveling in every direction. Second, developing a concept to ensure that the system's functions operate reliably in all types of driving situation.” [6]*

## Expectations and acceptance

We are clearly on the cusp of a creeping revolution in car safety. While those of us operating in the safety space understand the changes, realise the benefits and actively pursue safety improvements, it remains somewhat unclear as to whether consumers, en masse, share this position.

Baby boomers and Generation X may well find the rapid introduction of technology and the surrendering of control of the car difficult to deal with. On the other hand, Gen Y and Gen Z will likely embrace the technology, be oblivious to any sense of surrendering control and continue to go about their daily business with their eyes locked to their mobile technology devices. For them, an autonomous car will be very desirable.

Notwithstanding that technology has been part of our lives to a varying degree for at least 30 years; there are still many who resist. Yet today we are surrounded by technology and in particular automation when it comes to transportation. For example, aeroplanes, trains, and ships have had sophisticated autonomous technology for decades. Mining companies run their trains from hundreds or sometimes thousands of kilometres away. In some countries, like Japan, trains used for public transport are driverless. Loaded with sophisticated technology aeroplanes do many things autonomously and as a result flying has never been safer:

*“In the last five years, the death risk for passengers in the United States has been one in 45 million flights, according to Arnold Barnett, a professor of statistics at M.I.T. In other words, flying has become so reliable that a traveller could fly every day for an average of 123,000 years before being in a fatal crash,” he said.*

*“There are many reasons for this remarkable development. Planes and engines have become more reliable. Advanced navigation and warning technology has sharply reduced once-common accidents like midair collisions or crashes into mountains in poor visibility.*

*Regulators, pilots and airlines now share much more extensive information about flying hazards, with the goal of preventing accidents rather than just reacting to them. And when crashes do occur, passengers are now more likely to survive.” [7]*

If autonomous transport is already embedded in our lives; why not autonomous cars?

Perhaps it is because changes to cars seem to attract a far more personal and emotive response. For some it is an extension of themselves, a badge of honour, a social status indicator, an illustration of their abilities and often a defining element of their character. In these circumstances it is understandable why technology might be resisted.

Another influential consideration is the oft over-inflated view, shared by many, that he or she is the best driver on the road and everyone else is a bad driver; ‘it is the other idiots on the road that crash and kill themselves’. Adding to this view is a sense of infallibility and indestructibility and that driving skills will always win out if a dangerous circumstance presents itself. This too common view can fuel the resistance to technology.

The reality is that despite our over-inflated views, at some time in our driving experience we are all poor drivers. We all make mistakes, evidenced by the huge revenue raised by governments for traffic offences, and we all place ourselves in circumstances where luck rather than good management keeps us out of trouble.

The mistakes we make should not lead to death or serious injury, but human fallibility makes it nearly impossible to prevent mistakes from happening. Notwithstanding reluctance to embrace technology, when the SATs of tomorrow save your life, you will quietly affirm to yourself that despite your doubts you are glad you embraced the technology.

## Conclusion

It is estimated that 1.3 million people die in road crashes every year. [8] Most of these occur in developing nations. The costs of this tragedy are incalculably high.

In Australia, 1193 people were killed on our roads last year. Estimates vary but the number of seriously injured could be more than 30,000. [9] The costs of road trauma in Australia have been estimated by Government to be in the order of \$27 billion annually. [10]

Embracing safety assist technologies will put enormous downward pressure on road trauma in Australia and the world over. The faster this technology can be introduced and taken up by the market, the faster will be the rate of reduction in road trauma.

As a wealthy, developed and mature nation we have a responsibility to those in developing countries to use our expertise, influence and wealth to lift those countries over the mistakes we have made and place them at the forefront of car safety technology.

The technology of the very near future will hold some, but not all, of the answers. Nevertheless it is a future that holds

great promise in removing many of the risks of using a car and saving many lives.

In ten years we will look back and realise that the ‘cars for tomorrow’ have done their job.

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# ASEAN NCAP: Today and its future undertakings

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## Abstract

The New Car Assessment Program for Southeast Asian Countries, or ASEAN NCAP, is the newest addition to the established NCAP initiatives around the world. ASEAN NCAP is targeted to improve the safety aspects of private cars in the region, which come second in terms of volumes and the number of fatalities based on vehicle categorisation after the two-wheelers. As NCAP is originally focusing on crashworthiness evaluation via crash tests, more NCAP organisations have already put more focus on active safety by encouraging the fitment of Safety Assist Technologies (SATs) in new cars. ASEAN NCAP views SATs as a critical necessity in ASEAN countries since they not only bring a

crash avoidance element for cars but also can improve the situation on the road to address motorcycle issues.

## Keywords

ASEAN NCAP, Safety Assist Technologies, Vehicle safety

## Introduction

The journey to establish a New Car Assessment Program, in Malaysia began in 2007 when the Malaysian Institute of Road Safety Research (MIROS) was founded. The founder and inaugural MIROS Director-General, the late Professor Radin Umar Radin Sohadi, was the one who outlined the importance of NCAP in Malaysia as well as for the neighbouring countries. His strategic framework to introduce road safety interventions (Table 1) was developed based on the Haddon Matrix, in which most of them were included in the previous Malaysia's Road Safety Plan 2006 – 2010 [1].

In a brief overview about Malaysia's automotive history, particularly after the country had achieved its

independence, it can be divided into two main eras – the 1960's local assembly initiative and the national car project in the 1980's [2]. The former was mainly to encourage local assembly industries that had been inspired by the Colombo Plan experts, while the latter was to upgrade the country's car industry to another level by producing homegrown cars based on the National Car Policy idea mooted by Malaysia's former Prime Ministers, Tun Dr. Mahathir Mohamed. This advancement matched the "automotive development stages" predicted by the experts for developing countries such as Malaysia, in which the development starts with just importing CBU's to assembly of CKD's, then to embed local content in CKD's and finally to have a full scale manufacturing capability [3]. The only Malaysian born company that is able to reach that stage is Proton, while others are still in the second or third stage.

With regard to automobile safety development in Malaysia, there is nothing much to be said until Malaysia introduced UN Regulations in its Vehicle Type Approval (VTA) and the intention by MIROS to have the NCAP in the country. The local car manufacturers were having a rather slim chance to be assessed in any established NCAP due to its sales volume and market domination (import), while non-local manufacturers were still "selling" their foreign NCAP achievement for local commercials. This was the painful

moment for the safety promoters, e.g. the Road Transport Department (RTD), Road Safety Department (RSD) and MIROS, since some of those claims can be considered as half-truth. This has misled the consumers to blind "brand trust" without carefully looking at what is offered for local market from the specification sheet, let alone the reliable crash test to testify those claims. It is more often than not, that consumers come across the famous footnote guided by the asterisk – "*the specifications might be different from the car shown above*" – with the font size of probably four or below? Obviously, this is becoming a "normal practice" without anyone really caring to protect the consumers' right to the real understanding of car safety than just admiring the enlarged five-stars plate in the middle of the ads.

Therefore, the new era of automobile safety has presumably come at the right time in this new millennium years after the two abovementioned milestones that without a doubt had changed the country's automotive layout significantly. Furthermore, the ultimate benchmark is at the country's two largest automobile producers – Proton and Perodua. Those involved in the early days when NCAP in Malaysia was still on paper agreed that "vehicle safety" is the way forward for the auto industry in Malaysia. Proton has positively progressed in that aspect, from a donor car by Mitsubishi at the beginning to a model that had achieved three-stars

**Table 1: Road safety strategic interventions**

	<b>Pre-Crash</b>	<b>Crash</b>	<b>Post-Crash</b>
<b>Road User</b>	<ul style="list-style-type: none"> <li>➤ Road safety education</li> <li>➤ Driver training program and grading of driving institutes</li> <li>➤ Automated Enforcement Systems (AES)</li> <li>➤ Publicity campaigns</li> <li>➤ Community-Based Program (CBP)</li> <li>➤ Road user assessment program (RUAP)</li> </ul>	<ul style="list-style-type: none"> <li>➤ Compliance and correct use of Active Safety features</li> </ul>	<ul style="list-style-type: none"> <li>➤ Skills of paramedics and first respondents</li> </ul>
<b>Vehicle</b>	<ul style="list-style-type: none"> <li>➤ Vehicle Type Approval (VTA)</li> <li>➤ <b>NCAP Ratings</b></li> <li>➤ Rear seatbelt</li> <li>➤ Under-run for HGV</li> <li>➤ Vehicle inspection</li> </ul>	<ul style="list-style-type: none"> <li>➤ Passive safety system</li> <li>➤ Crash compatibility</li> </ul>	<ul style="list-style-type: none"> <li>➤ Ease of evacuation tools</li> </ul>
<b>Road and Environment</b>	<ul style="list-style-type: none"> <li>➤ Road safety audit</li> <li>➤ Black spot treatment</li> <li>➤ Motorcycle lanes</li> <li>➤ iRAP</li> </ul>	<ul style="list-style-type: none"> <li>➤ Clear zones</li> <li>➤ Barrier systems</li> <li>➤ Crash cushions</li> </ul>	<ul style="list-style-type: none"> <li>➤ Easy access by first respondents</li> <li>➤ Trauma centre</li> </ul>

in Euro-NCAP's adult occupant safety (Proton Waja; or Impian in the United Kingdom's market), and finally the Proton Prevé that has bagged five-star status in an overall assessment by the Australasian NCAP (ANCAP) in 2013 [4]. Perodua, on the other hand, still has much influence from its Japanese counterpart – Daihatsu – so it was not a “worrisome situation” to the group of “NCAP believers” that Perodua will be left behind since the “economic competitiveness” in the domestic “automotive ecosystem” was still the main concern.

## The Development of ASEAN NCAP

The Malaysian Vehicle Assessment Program (MyVAP) came into the picture in 2009, which had expectedly received mixed reactions especially by the manufacturers. The inception of MyVAP was intended to fill the gap in the industry prior to what is called the “Malaysian NCAP” or “MyNCAP” initiative. MyVAP is an exercise similar to NCAP (primarily in giving star ratings to car models) but only using “secondary data” voluntarily provided by the participating manufacturer. Even though the exercise is mostly paper-based, the knowledge that grows from this activity was incredible to the “NCAP team” at MIROS [4].

In about three years of MyVAP era, only local manufacturers Proton and Perodua had participated with both bringing forward their best two models. It started with Proton Exora (four-star), Perodua Alza (four-star), Perodua Myvi (four-star) and finally by the only five-star MyVAP car, Proton Prevé [4]. Meanwhile, the non-local manufacturers had been closely monitoring the progress of MyVAP, though their hesitation to be involved in the exercise was quite apparent. Nevertheless, there was a notable scenario of increased safety items for new cars in the market and since then many models were launched with the likes of airbags and anti-lock braking system (ABS) as standard fit. In 2012, MIROS – though without any specific recognition – had concluded that MyVAP was a successful “soft-landing program” for three reasons: (1) local manufacturers had the readiness and ample time to cope with the more stringent scheme in NCAP; (2) the message was conveyed to the internationally established manufacturers who are apparently able to meet NCAP requirements in the developed market; and (3) MIROS had ample time for its capacity building in both know-how and preparing the necessary facilities (crash lab).

The World NCAP, an initiative led by the Australasian NCAP (ANCAP), had changed the game plan in which the first manufacturer meeting with the Japanese manufacturers was held in Tokyo in October 2010. This was an important move since the Japanese manufacturers dominated the Southeast Asian market including Malaysia. Furthermore, the most important point in the journey of ASEAN NCAP then came after the newly-established Global NCAP – an organisation supported by the FIA Foundation to materialise

the Safer Vehicle Pillar in the United Nations' Decade of Action – led the way to ASEAN NCAP establishment in November 2011. A Memorandum of Understanding was signed in Delhi, India between MIROS and Global NCAP to establish a regional-based NCAP called ASEAN NCAP, in which for MIROS it became a bigger initiative than the original idea of MyNCAP [1].

Furthermore, MIROS during the same period had started to build their very own crash laboratory after three years of research and development works. This self-designed crash lab project called MIROS PC3 held its first crash test on 24th May 2012 during the Automotive Safety Week Southeast Asia (2012) event in Melaka, Malaysia, in conjunction with the inaugural Global NCAP Annual Meeting [5]. Since then, the regional NCAP program has grown extensively with strong support by other established NCAPs as well as the world's prominent crash testing equipment suppliers. Among others, the Australasian NCAP (ANCAP) had contributed significantly to ASEAN NCAP establishment in the form of organisational and technical support [6].

To date, ASEAN NCAP has completed two phases of evaluation with 19 passenger cars' variants and is expected to complete the third and final phase of the so called “pilot stage” by the end of the first quarter in 2014. The earlier two phases have incorporated frontal offset deformable barrier (ODB) tests at the closing speed of 64 km/h (Figure 1). From this single crash test, the evaluation is done in two forms – the Adult Occupant Protection (AOP) based on the injury performance from the adult dummies on the front seats (Hybrid III 50th-ile; driver and front passenger), and the assessment of Child Occupant Protection (COP) based on the child dummies' injury assessment and physical examination of the “child seat-friendly” characteristics. The former is marked by star rating where five-star is the best, while the latter is rated by percentage where 100 percent is the best. Table 2 describes the results from ASEAN NCAP's first two phases.

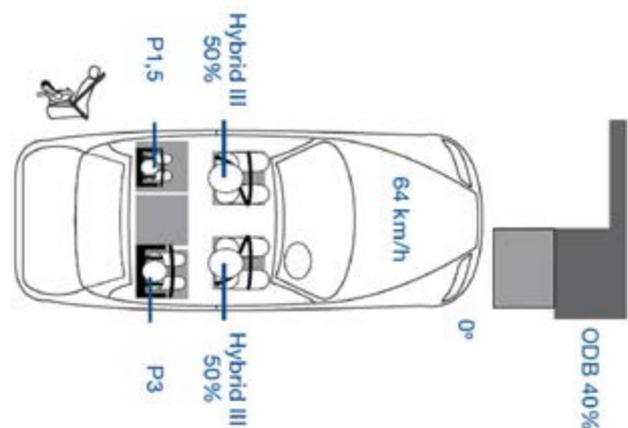


Figure 1. ASEAN NCAP frontal offset test configuration (64 km/h)

Moreover, in the first two phases, a pre-requisite was also introduced in AOP rating whereby only cars that are equipped with seat-belt reminder (SBR) for both driver and front passenger and the Electronic Stability Control (ESC; or similar technology) are eligible for five-star. This means the failure to meet both requirements by a five-star car from the crash test will be penalised to four-star [1]. ASEAN NCAP is committed to bring the ASEAN NCAP assessment to the level of other established NCAPs; therefore, new requirements in the assessment scheme have been deliberated with the manufacturers (ASEAN NCAP OEM Meeting Series) in a dynamic but progressive road map. From Phase Three onwards, ASEAN NCAP has introduced another pre-requisite based on the UN Regulation No. 95 (R95; lateral impact). This pass-fail R95 conformation test will be another pre-requisite to determine the eligibility to be awarded four-star and above. It has now become a common understanding that this current ASEAN NCAP's assessment scheme will remain until December 2016,

since after that ASEAN NCAP is expected to introduce a “combined rating” from multiple assessments/crash tests.

## Future challenges to ASEAN NCAP

The main concern in road safety for the ASEAN region goes to the motorcycle issues that push the intriguing mind to the question of “how relevant is NCAP for ASEAN now?” Nevertheless, the ASEAN NCAP movement is important for two obvious reasons: (1) NCAP and crash test for passenger cars are established programs in which the assessment is more “objective” and widely accepted to improve the situation; and (2) the same initiative for motorcycles has a “long way to go” since the vulnerability of motorcyclist on the road is a totally different issue as compared to car occupants. Therefore, the medium-term plan in ASEAN NCAP should also look into giving the benefits to motorcycle users through NCAP. With so many new technologies introduced for passenger cars, NCAP should further promote these “active safety” elements in

**Table 2: ASEAN NCAP results from Phase I and II**

Make and Model	Origin	Airbag	AOP : Star <sup>b</sup>	COP	Note
<b>PHASE I</b>					
Ford Fiesta	Thailand	7	15.73 : <b>5</b>	66%	Not affected by SAT
Honda City	Malaysia	2	15.44 : <b>(4) &amp; 5</b>	81%	4-star for tested variant (ESC)
Toyota Vios	Malaysia	2	13.61 : <b>4</b>	48%	Not affected by SAT
Nissan March	Thailand	1	11.66 : <b>4</b>	48%	Not affected by SAT
Proton Saga FLX+	Malaysia	2	10.23 : <b>3</b>	58%	Not affected by SAT
Perodua Myvi	Malaysia	2	8.71 : <b>3</b>	54%	Not affected by SAT
Hyundai i10	Malaysia	2	7.31 : <b>2</b>	48%	Not affected by SAT
Proton Saga <sup>a</sup>	Malaysia	1	4.30 : <b>1</b>	49%	Not affected by SAT
<b>PHASE II</b>					
Toyota Prius	Japan	7	15.30 : <b>5</b>	86%	Not affected by SAT
Honda Civic	Thailand	2	14.63 : <b>(4) &amp; 5</b>	82%	4-star for tested variant (ESC)
Subaru XV	Japan	3	14.31 : <b>5</b>	67%	Not affected by SAT
Suzuki Swift	Malaysia	2	13.32 : <b>4</b>	77%	Not affected by SAT
Mazda 2	Thailand	2	13.10 : <b>4</b>	78%	Not affected by SAT
Mitsubishi Mirage	Thailand	2	13.07 : <b>4</b>	43%	Not affected by SAT
Toyota Avanza	Indonesia	2	12.98 : <b>4</b>	38%	Not affected by SAT
Perodua Alza	Malaysia	2	12.86 : <b>4</b>	46%	Not affected by SAT
Nissan Almera	Thailand	1	12.74 : <b>4</b>	52%	Not affected by SAT
Daihatsu Xenia	Indonesia	2	12.34 : <b>4</b>	33%	Not affected by SAT
Mitsubishi Pajero Sport	Thailand	2	12.08 : <b>4</b>	40%	Not affected by SAT

<sup>a</sup> Proton Saga (Phase I) was taken out from market since the second quarter of 2013.

<sup>b</sup> Parentheses – ( ) – refer to the tested variant. ASEAN NCAP did recognise the variant that offered ESC as standard fit (five-star) as happened in both Honda City and Honda Civic case.

new cars. These safety technologies, also known as Safety Assist Technologies (SATs), will not only benefit the car users especially in minimising the risk of getting involved in road crashes but also “protecting” motorcyclists from similar risks.

The latest technology that has been considered in our road maps is the Blind Spot Detection and Automatic Emergency Braking (AEB). These two technologies are perhaps the best bet to complement ESC and SBR that are already in the rating structure. More technologies, categorised as the Advanced Driver Assistance System (ADAS), are now becoming a trend in modern cars. They are meant to reduce accident probability and indirectly to reduce possible injuries from road crashes. Furthermore, it is hoped that these technologies could reduce the alarming number of motorcyclists’ fatalities in the region, which sums up to 50% from all road user’s categories. For example, in Malaysia alone, the number of fatalities among motorcycle users is more often than not exceeding 50 percent of the annual total death toll [7].

Nevertheless, the rationale to promote more SATs will very much depend on available infrastructure and environment. For example, Lane Departure Warning (LDW) will become a witticism if the lane itself does not exist (multiple lanes carriageway) in certain countries or regions in a country. Another challenge is that ASEAN NCAP, due to its limitation of test facility and assessment capability, will not be able to evaluate the SATs functionality and effectiveness objectively. Still, ASEAN NCAP will keep promoting SATs, in which the “quick win” strategy is through the “pre-requisite” requirement in the rating scheme.

On the other hand, the ASEAN community in general is obviously far away from what is called “autonomous driving”. The recent development of such safety technology is eminent in developed countries such as Japan, Europe and the United States. A Japanese manufacturer, Nissan, has already announced that the system would be available by 2020 [8]. Optimistically this can be done if the infrastructure, environment and technology can fit into the required level in Intelligent Transportation System (ITS). For example, Japan is looking seriously into this via their comprehensive ITS framework and their high-end infrastructures. At ASEAN NCAP level, manufacturers are encouraged to develop what is “friendly” to the ASEAN transportation system. There is a possible recognition from ASEAN NCAP in its future Grand Prix award to any effort to improve active safety via SATs and ITS.

It is believed that ASEAN NCAP will reach its maturity in passive safety assessment by 2017. Passive safety that generally involved various crash test configurations – pedestrian protection, pole impact, etc. – is a rather straightforward effort since the first and greatest hurdle had already been overcome by MIROS through the establishment of the MIROS PC3 crash laboratory. The remaining challenges are to include the abovementioned tests into the rating scheme (2017 onwards). This basically

means MIROS and ASEAN NCAP have to ensure enough financial sources to implement more tests.

## Conclusion

In today’s modern society, safer mobility has become a critical concern in both developed and developing countries. However, the need for a great improvement in the transportation system is explained by the fact that 90 percent of road fatalities occurred in low and middle-income countries. This indicates that, mobility is not only about accessibility but also it must address sustainability in terms of affordability and most importantly the access to safety. Therefore, ASEAN NCAP has to work together with the vehicle manufacturers and also to educate the users or specifically car owners, in order to achieve the ultimate outcome from the NCAP initiative.

Michelangelo once said, “*The greater danger for most of us is not that our aims are too high, and we miss it, but that it is too low, and we reach it.*” ASEAN NCAP’s challenge in the next five years is not only about producing safer cars but most importantly to establish the “safety brain” in each ASEAN country as the agent of car safety. By participating in automotive conferences all over the ASEAN region and launching the results in various ASEAN cities, it is expected that the information of ASEAN NCAP will be further distributed and well-understood. Therefore, the more consumers purchase safer cars based on ASEAN NCAP results, the more positive outcome will prevail on ASEAN roads.

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## Navigating toward zero fatalities: the role of NCAPs

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In the nearly 20 years since the Insurance Institute for Highway Safety (IIHS) began publishing crashworthiness ratings for consumer information, great progress has been made in reducing the toll from motor vehicle crashes in the United States. The drop in deaths and injuries during that time continued a trend that began in the 1970's. Along with important changes in people's behaviour spurred by cultural and legislative shifts - notably a reduction in alcohol-impaired driving and wider use of seat belts - the improved safety of vehicles has been a key factor in this drop.

When we look at the crash statistics and compare the vehicles being sold today with those of just a few decades ago, the United States appears to be sailing inevitably toward the goal of zero fatalities. The crash death rate per capita has fallen by almost half since 1975 and the fatality rate per billion miles travelled went from 34 in 1975 to 11 in 2012 [1]. Frontal and side airbags, as well as electronic stability control, are now virtually universal in new passenger vehicles and systems capable of stopping some crashes altogether are rapidly spreading. Autonomous driving is coming in the not-too-distant future, with the technological groundwork already laid.

But the destination of near-zero fatalities is a lot farther than it appears when looking out from the bow of the highway safety ship. It will take a lot of work to move the ship in the right direction over the long journey.

### Steering the ship with safer vehicles

The research community is good at figuring out which vehicle features can reduce fatalities and injuries, and New Car Assessment Programs (NCAPs), including the IIHS vehicle ratings program, have encouraged manufacturers to adopt these features. Government regulation has, in some cases, sped things along even further.

But even when a feature is mandatory in new vehicles, it still takes decades before all vehicles on the road are equipped with it. A study by our affiliate, the Highway Loss Data Institute, found that it takes about three decades or longer from the time a promising safety feature is introduced until it is on 95 percent of registered vehicles [2].

The reason is simple: Just because a feature is available does not mean the entire driving population will immediately go out and replace their vehicles. Given the current conditions of approximately 240 million registered passenger vehicles and about 10 million new vehicles registered a year, it would take about 24 years for the fleet to completely turn over (not counting classic cars and vehicles that people hold on to for sentimental reasons). In reality, it takes longer because not every new vehicle replaces one of the oldest.

Take, for example, electronic stability control. ESC was first introduced in the United States in the 1995 model year and quickly proved its worth. The most recent IIHS study found it reduces fatal crash involvement risk by 33 percent - 20 percent for multiple-vehicle crashes and 49

percent for single-vehicle crashes [3]. Previous studies had shown similarly large benefits, prompting us to make the technology a requirement for our award, *TOP SAFETY PICK*, beginning in 2007. The U.S. government began phasing in a requirement for ESC with the 2009 model year; all new passenger vehicles have had it since the 2012 model year.

Despite all these efforts to encourage the quick adoption of ESC, the technology is predicted to be available on 95 percent of the vehicle fleet only in 2029 (Figure 1).

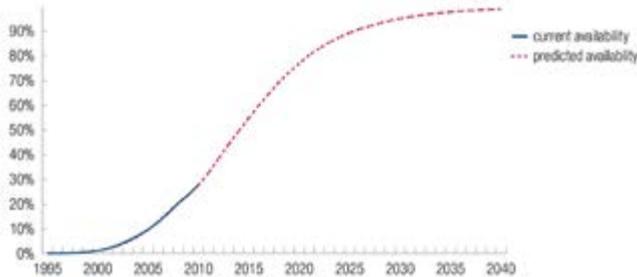


Figure 1. Predicted percentage of registered vehicles with ESC

It is important to note that availability means just that: HLDI counted vehicles for which a given technology was either standard or optional, meaning the actual presence of ESC in the vehicle fleet will be less than 95 percent in 2030.

In short, our ship turns slowly, and that makes steering correctly that much more important. Safety advocates need to agree on the course we are taking. Are we committed to maintaining and improving crashworthiness? What role will crash avoidance play and what shape will that take in the future? Autonomous vehicles? Vehicle-to-vehicle (V2V) and vehicle-to-infrastructure (V2I) communication? Some combination of the two? In addition to maintaining a steady course, it is imperative that NCAPs work in close cooperation with regulators to keep them abreast of our trajectory and vice versa. For example, IIHS and other ratings organisations currently are encouraging the adoption of self-contained crash avoidance systems, while governments have been putting research dollars into V2V and V2I. These technologies are not necessarily at odds with each other but must be coordinated.

## Staying the course

IIHS has been successful in large part because we move methodically and deliberately. We have been supporting and conducting highway safety research for more than half a century; long before we began our ratings program. Throughout this history, whenever research has confirmed the value of a given countermeasure, we have pushed for it and kept pushing.

Our work on truck underride is just one example. IIHS first demonstrated the inadequacy of the U.S. standard for

rear underride guards - the metal bars on the backs of large trucks meant to keep a passenger vehicle from traveling underneath in a crash - in the mid-1970's [4]. We crashed 1976 Ford Granadas and 1976 Chevrolet Chevettes into the backs of parked semitrailers, first with the trailer manufacturer's underride guard and then with one of two prototype guards developed by IIHS. In each of the crashes using the manufacturer's guard, the resulting intrusion into the occupant compartment was devastating, and in a real crash the driver would have been killed. When the same tests were conducted with our prototypes, there was no underride.

Despite our tests, the pace of government regulation in this area remained disappointingly slow. Finally, in January 1998, an updated rear underride guard standard took effect. This new standard improved the strength of the guards but still was not tough enough. In 2010, IIHS studied how guards built to comply with the federal standards were performing in real-world crashes and found that many failed, allowing severe passenger vehicle underride and resulting in serious or fatal injury [5]. IIHS petitioned the government to improve the standard and conducted more tests in hopes of having a direct influence on trailer manufacturers [6]. After the underride guard on a Hyundai Translead trailer failed to hold up in our test, the company came back with a redesigned guard that performed much better.

Our latest series of car-into-truck crash tests in 2013 showed that current-generation underride guards exceed the U.S. requirements and work well when passenger vehicles strike the centre of the trailer's rear. However, the tests showed that trailers from seven of the eight largest manufacturers do a poor job of preventing underride in crashes involving only a small portion of the truck's rear. Rear underride continues to be an issue, which means you can expect more work from us in this area.

Our vehicle ratings program is not quite as old as our underride work, but here too we keep a firm hand on the tiller. IIHS currently maintains ratings for close to 200 models. We first began putting vehicles through the moderate overlap frontal crash test in 1995. Automakers quickly incorporated protection in such crashes into their new designs. We added a side impact test in 2003, a dynamic evaluation of head restraints and seats for rear crash protection in 2004, and a roof-strength test in 2009. Each time, manufacturers responded quickly, and the majority of models sold in the U.S. today earn good ratings in all four of these tests.

We continue to raise the bar with our vehicle ratings. To achieve our highest award for 2014, *TOP SAFETY PICK+*, a vehicle must earn good ratings in the moderate overlap front, side, roof strength, and head restraint tests, as well as a good or acceptable rating in the small overlap front

test that we introduced in 2012 and a basic or higher rating for front crash prevention. Next year, the criteria will be tightened again.

Staying the course does not mean we do not ever adjust our navigation, however. Research plays a key role in alerting us to obstacles and guiding us toward favourable currents.

At the moment, there is a critical need for more research into advanced crash avoidance technologies, so that we can learn which features are effective. Results in the real world do not always conform to expectations based on track tests or in pilot studies because it is difficult to predict how drivers will react to a safety feature after it becomes widespread.

Two examples from a few decades ago demonstrate how features that show promise initially can fail to live up to expectations. Antilock braking systems perform well on the test track, but studies have found reductions in real-world crashes ranging from none to small and no effect on fatal crashes [7]. Real-world results of centre high mounted stop lamps (CHMSLs) were similarly disappointing. Required on all new passenger vehicles in the United States since the 1986 model year, these supplemental brake lights were predicted to cut relevant rear-impact crashes by half in urban areas. However, a study of insurance claims found CHMSL-equipped vehicles had only five percent fewer rear-end collisions than would have been expected without the additional brake lights [8].

While data are still scarce on many of the newest crash avoidance features, HLDI has been able to provide an early look at their effects through the claims data it collects from U.S. insurers. These studies show that front crash prevention systems, including forward collision warning and autobrake systems, are reducing crashes, as are adaptive headlights [9]. The effects of other systems are less clear. Initial HLDI analyses suggest that at least one feature, lane departure warning, may not live up to expectations. More research is needed to explain why that might be the case and whether the systems can be improved.

## Tides, winds and current

It is the goal of NCAPs, in partnership with other highway safety advocates, to chart the course and help maintain it through our influence on consumers, governments and automakers. As we do so, we need to take into account the tides, prevailing winds and underlying current. In the United States, government and public appetites for regulation tend to go up and down, depending on which party is in office and the politics of the moment. Economic and geopolitical crises can create temporarily unfavourable winds.

The HLDI study on the spread of safety technologies provides an example of how such factors can slow progress. Frontal airbags fit into the approximately 30-year timeline for 95 percent fleet penetration if the process is considered

to begin in the 1984 model year. In fact, the first airbags were available on cars sold in the United States in the early 1970's, but the domestic auto industry subsequently declared airbags unfeasible and lobbied against them. This was at a time when the industry and the nation were grappling with an oil crisis and an economy so bad it inspired the creation of a new metric called the "misery index," a combination of the unemployment rate and inflation rate. In 1980, Ronald Reagan was elected president on a pledge to rein in what he saw as excessive government regulation. These trends slowed the progress of airbags considerably, and it was not until after the U.S. Supreme Court ruled in favour of insurers' efforts to get airbags into passenger vehicles that this life-saving innovation took off in the U.S.

In today's world, a constant factor that safety advocates must consider is the underlying current of climate change and the pressure to reduce carbon emissions. To stay on course in this environment, NCAPs have to resist calls to accept the safety tradeoffs of lighter vehicles and instead encourage the growth of more efficient hybrid and electric technologies.

Although we all have the same zero-fatality destination in mind, NCAPs around the world are travelling on separate ships and coming from different ports. As a result, the tides and winds will affect us differently and the voyage will be longer for some than for others. In emerging markets, for example, the desire for cars that are affordable to a wide swathe of the population has resulted in a lack of consumer and government pressure for basic safety features. About a third of new vehicles sold worldwide fall short of the basic frontal crash protection provided by models sold in the United States, Europe, or Australia [10]. So, while the latest segment of our safety journey is being powered in part by sophisticated crash avoidance features, safety advocates in markets such as Argentina, Brazil, Indonesia, Malaysia and Mexico have different needs in the short term. Conversely, some smaller European markets such as Sweden are ahead of the United States. Their smaller vehicle fleet means they have a more nimble ship and their safety-conscious culture puts wind in their sails. These leaders will help chart the course for the rest to follow, identifying obstacles and barriers to be avoided.

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## The European New Car Assessment Programme

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### Introduction

The European New Car Assessment Programme (Euro NCAP) provides consumers with a realistic and independent assessment of the safety performance of some of the most popular cars sold in Europe. The organisation has an important influence on vehicle designs, leading to fewer traffic deaths on European roads.

Established in 1997, Euro NCAP is a non-profit international association independent of the automotive industry. It is backed by seven European governments (France, Germany, Sweden, the Netherlands, the United Kingdom, Luxembourg, and the Catalonia region of Spain); consumer groups through International Consumer Research and Testing organisation; European motoring clubs through the Fédération Internationale de l'Automobile (FIA Region 1, ADAC and ACI); and UK insurers through the Motor Insurance Repair Research Centre (Thatcham).

Euro NCAP's headquarters are in Brussels, Belgium, close to the European Commission and Parliament. Testing of vehicles is carried out at seven accredited laboratories

located in six Member States of the European Union: ADAC, BAST, CSI, IDIADA, Thatcham (with MIRA) and TASS.

Over the last 17 years, Euro NCAP has tested more than 500 vehicles, including superminis, small and large family cars, executive cars, MPVs, SUVs, pick-ups, roadsters and vans.

### Current and future crash tests

Vehicle buyers owe it to themselves and their families to choose the safest vehicle. To do so they need reliable, accurate and unbiased comparative information regarding the safety performance of individual models. In Europe, all new models must, by law, pass safety tests before they are sold, but these are minimum standards and the buying public is not informed about how well cars pass these tests. Euro NCAP encourages manufacturers to exceed the minimum requirements and ensures that car buyers can make an informed decision by issuing an easy-to-understand star rating for most popular cars.

Since 2009<sup>1</sup>, Euro NCAP has released an overall safety rating with a maximum of five stars for each vehicle. The rating is comprised of scores in four important areas:

- Adult protection (driver and passenger);
- Child protection;
- Pedestrian protection, and
- Safety assist technologies.

The underlying tests include full-scale frontal offset and side-impact barrier and pole tests, front-end component tests for pedestrian protection and seat sled tests for whiplash prevention in rear-end crashes. Seat belt reminders, speed limiters and electronic stability control also contribute towards a vehicle's rating. The overall score is calculated by weighing the four scores with respect to each other, while making sure that no single area is underachieving.

The overall rating scheme was introduced to provide a more balanced assessment of various vehicle safety aspects and to add more flexibility to the ratings scheme. In recent years, Euro NCAP has worked on a programme of stepwise updates to the rating scheme, focussing on the upgrade of existing crash tests and on adding tests of emerging crash avoidance and advanced driver assistance technologies:

### Adult occupant protection

In 2014, the assessment of whiplash neck injury has been extended to the rear seating positions. In 2015, an updated set of crash tests for front and side protection will be implemented, including a new full-width frontal crash test and updated barrier and pole tests. What Euro NCAP hopes to achieve is, amongst other things, better restraint systems for the rear passengers. For the full width frontal test this will be realised by assessing the risk of injury of a small female occupant, controlling forward head excursion and chest displacement and penalising the tendency to submarine (where the pelvis slides under the lap belt, resulting in abdominal injuries). The updated side barrier test will use a mobile barrier that is heavier, stiffer and wider than that used today and a more advanced side impact dummy in the driver seat. In addition, the new oblique pole test, aligned with the GTR procedure, will apply a geometric assessment of the head protection device. This will assess the area covered by side thorax/head or curtain airbags in both front and rear positions for different sizes of occupants as shown in Figure 1.



**Figure 1.** In 2015, the Euro NCAP side impact crash tests will be updated with new elements such as the Advanced European Mobile Deformable Barrier (AE-MDB) and the WorldSID mid-sized male dummy.

### Child occupant protection

In 2013, Euro NCAP introduced a child seat installation check and changed from P to Q dummies for the dynamic assessment. The installation check promotes better compatibility between vehicles and the most popular types of child restraints on the European market, an area which is often a cause of problems in the real world. Further updates are scheduled in the coming years, most importantly a change to taller child dummies - 6 and 10 year old - for the dynamic tests to cover the transitional size group between those children in integral child seats and adults. Finally, Euro NCAP will provide incentives for vehicle makers to design their vehicles to be compatible with seats approved according to the new UN R129 "i-Size" standard.

### Pedestrian protection

Step-wise updates to the subsystem (adult and child headform, lower leg and upper legform) tests have been introduced since 2010. Firstly, the headform impactors were harmonised with those specified in the GTR and European Regulation. Longstanding industry criticism about subjective impact location selection was addressed by implementing a grid approach first for bonnet and subsequently for bumper and bonnet leading edge testing. At the same time, the scope of the protocol was extended by incorporating the verification of deployable protection devices, such as pop-up bonnets. Finally, the lower leg test device was updated to the Flex PLI impactor with new criteria and limits in 2014 (Figure 2).

In 2015, the last of the test procedures, the upper leg test, will be updated to improve the correlation between real world injuries and assessment scores. The impact height will be standardised to match the estimated impact location of the adult male hip and new criteria and limits have been agreed.



**Figure 2.** The Flex-PLI is used from 2014 to assess pedestrian knee and tibia injury risk.

## Advanced safety technology

The assessment area of Safety Assist was introduced to the rating to reflect the increasing importance of rapidly emerging crash avoidance technology. While only a few safety assist technologies were included initially (Seat belt reminders, Speed Limitation Devices and Electronic Stability Control), it is clear that considerable safety benefits can be realised by rewarding wider fitment of robust crash avoidance and driver assistant systems.

### Safety assist

Following the implementation of the ESC test in the rating scheme in 2011, the assessment of Speed Limitation devices was broadened in 2013 to include intelligent Speed Assistance Systems which employ digital mapping and/or speed sign recognition. In 2014, lane support systems were added to the assessment, as well as autonomous emergency braking systems (which may also include forward collision warning) which help to avoid or mitigate rear-end crashes both at high and low speeds. This will be followed in 2016 with the inclusion of Pedestrian Detection technology (as part of the Pedestrian Protection assessment).

### Rewarding new technologies: Euro NCAP Advanced

Since 2010, Euro NCAP has been rewarding vehicle manufacturers that make available new technologies which have a scientifically proven safety benefit for consumers and society but are not yet considered in the rating scheme. Many of these technologies focus on avoiding crashes by informing, advising, alerting or supporting drivers in dangerous situations. Recognising these advances under Euro NCAP Advanced provides an incentive to manufacturers to accelerate the availability of new safety equipment across their model ranges, helps vehicle buyers factor these features into their purchasing decisions and paves the way for inclusion of these technologies in the rating scheme (Figure 3).



Figure 3. In 2010, Honda was presented with one of the first Euro NCAP Advanced rewards for their Collision Mitigation Brake System (CMBS) technology.

## Driverless cars

The idea of automated and self-driving cars has been widely aired in technical discussions and in media coverage recently. The rapid development of electronic safety systems has made the concept possible and prototype systems are able to “drive” in controlled situations. The established vehicle industry is active in this field but new players such as Google have also shown prototypes. There is no doubt that greater automation will lead to a revolution in safety, putting it above all other requirements and characteristics of a car. Not only will the self-driving car have the technology to sense, avoid and mitigate in potential crash scenarios, it will also drive in a safer manner. Besides that, used in a manual way, the vehicle will always carry the safety elements and technologies to intervene when necessary. Euro NCAP plans to engage in the roll out of vehicle automation as a way to dramatically improve vehicle safety and safe driving. It will continue to promote best safety practice when vehicles start to have elements fitted which support automated driving and to ensure that the vehicle manufacturer remains responsible for safe operation of the system.

### Changing the rating

Each year, the development and updating of test and assessment protocols constitutes a significant effort by Euro NCAP, its members and their laboratories. Through its assessments Euro NCAP promotes “best practice” and the state-of-the-art in safety design, often looking beyond what is available on the market today. For this reason, it has over time involved key representatives from the vehicle manufacturers, suppliers and, occasionally, third parties in the development of new procedures.

The development process for new procedures has evolved over the last years with the aim to provide more transparency and to set reliable and stable targets for industry. Euro NCAP aspires to follow the market closely and reward those vehicle manufacturers who show leadership in safety. Hence, a flexible approach is taken where, for each individual subject, the severity of new test requirements and the potential impact on the vehicle design are carefully balanced with the benefit to consumers and the ability to give credit to industry leaders.

A significant effort is also required to communicate changes in the rating system to consumers. This includes a clear explanation of the meaning of the star rating.

### Challenges in the next five years

New cars today are much safer than they were a decade ago thanks to improved crash test standards, crumple zones, seatbelts and airbags which help protect occupants in a crash. While most occupant safety measures can be

considered mature, more could and should be done to improve their robustness for the general diversity of vehicle occupants and crash scenarios.

Crash avoidance systems can help prevent accidents from happening in the first place. They should be effectively deployed to address the above key accident scenarios, including those that involve other road users and commercial vehicles. Today, the uptake of crash avoidance technology still poses a particular challenge: a large variety of systems are available but only a few are offered as standard. The uptake of optional systems is still low and depends greatly on market incentives. In the coming years, the need for more onboard technologies to support (partial) automated driving will probably make crash avoidance systems cheaper and more cost-effective across the European car fleet.

Besides the price, acceptance and volume of advanced technologies are driven largely by how well consumers understand these features and value them. For this, the vehicle rating must reflect the true contribution of passive and active safety measures to the overall safety performance. The lack of traceability of (the performance of) systems in the market, the complex role of driver behaviour and inconsistency in Human Machine Interface (HMI) applied across industry, all further complicate the important task of identifying the true potential of avoidance technology.

## Notes

1. Before 2009, Euro NCAP published three independent ratings per car: adult occupant protection, child occupant protection (as of 2003) and pedestrian protection.

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# Promotion of traffic safety by NCAP in Japan: aiming to be the safest country of road traffic in the world

by *Hiroyuki Inomata*

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## Introduction

The number of casualties reported to police caused by road traffic accidents is tending to decline in Japan; in 2013, 4373 were killed. However the rate of decrease is getting lower whilst the number of deaths in the elderly is increasing and the number of seriously injured (Severe disability) is staying at the same level. (See figure 1).

On the other hand, the Japanese government has proposed outcomes that make the number of deaths less than 3,000 in 2015 and 2,500 by 2018: aiming to be the safest country of road traffic in the world as represented in the OECD statistics.

## JNCAP efforts and effect

In Japan, the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) is working on the safety of the vehicle technology and road safety policy, by linking three measures. One is JNCAP, and there is collaboration with the National Agency for Automotive Safety and Victims'

Aid (NASVA). (See figure 2). NASVA is a specialised agency in Japan for the victims, supporting those who have been seriously injured by road traffic crashes and also their families financially and mentally. NASVA's service includes an aptitude test for professional drivers and promoting training sessions for operational management personnel. NASVA also provide JNCAP with a fair and neutral point of view, and performance evaluation results are reviewed with technical WG and finalised by experts and academics in the JNCAP steering committee which is held by MLIT and then published. This will expedite the technological development of vehicle high safety performance by the manufacturers. And the published results enable consumers to choose safer cars by emphasising public interest in these safety aspects.

As for the effect of JNCAP, if it were not for safer vehicles on the market today, about 5,000 more deaths would have been reported on our analysis of past 80,000 cases of road traffic accident data in 13 years from the benchmark when JNCAP launched. (See figure 3)

## JNCAP performance evaluation and their characteristics

This section shows the JNCAP framework which carries out mainly five performance evaluations on vehicles:

1. Passenger Protection (Collision safety) performance evaluation,
2. Pedestrian Protection performance evaluation,
3. Seat belt reminder performance evaluation for passenger seat and rear seat
4. Usability evaluation for rear seat belt
5. Brake performance evaluation

For Child restraining system (CRS) performance evaluation, we have been testing by sled and usability test.

## Characteristics of each evaluation

### Passenger Protection (Collision safety) performance evaluation

Two kinds of frontal collision test, offset and full-frontal, side impact collision test using MDB, neck protection performance test (whiplash test) by sled are carried out. In the three collision test, protection against electric shock is also evaluated by inside and outside of the vehicle that

uses a high voltage battery on electric vehicles or a hybrid vehicle.

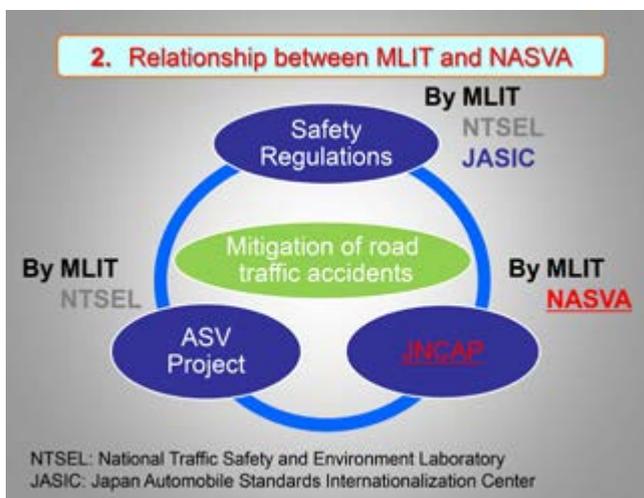
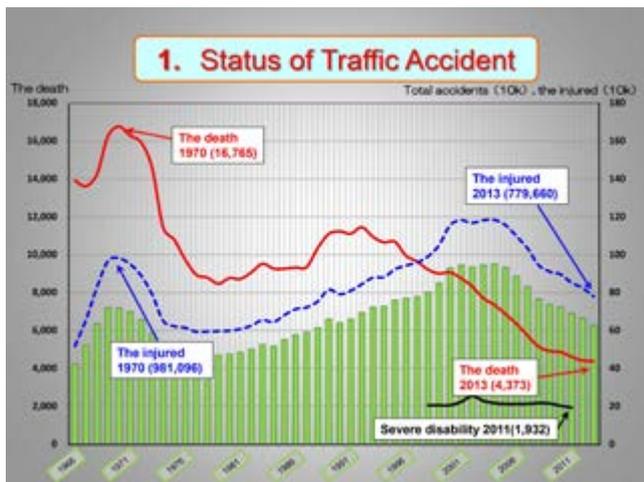
We place an AF05 female dummy on the rear seat in the offset collision test and inspect chest deformation and submarine phenomenon in order to define the occurrence of the lap belt coming off from the proper position (pelvis). Women and the elderly are often seated in rear seats in Japan. In addition, it is observed that a passenger who is wearing a seat belt is more likely to be killed with abdominal (cavity) bleeding because of this submarine phenomenon. This evaluation was adopted as the number of fatalities is reported to be increasing in real world accidents.

In a recent JNCAP result, one model has rated as level one, as this evaluation is difficult to gain points. Recent trends show vehicles equipped with pretensioner system and force-limiter system or both on rear seats gain good points. The effectiveness of JNCAP here is obvious. The model which has got a level one result took a so called “revenge test” after they made some improvements in their design for safety performance and got better points.

### Pedestrian protection performance evaluation

The reduction rate of pedestrian casualties stays flat while the total number of killed on the road is declining. Car occupants and pedestrian deaths figures have reversed in 2008 and the gap between them is growing. JNCAP has been working on Pedestrian Protection performance evaluation and are taking this issue quite seriously. Head and leg impactors are used in the test. JNCAP consider further improvements in pedestrian safety by introducing higher test speeds of impactors.

In a recent result of JNCAP, a vehicle equipped with a pop-up bonnet designed to reduce head injury by popping up the bonnet in a collision with a pedestrian, achieved high points. We can see diffusion in the Japanese market as the result of JNCAP.



## Seat belt reminder performance evaluation for passenger seat and rear seat

The seat belt reminder system with the driver seat is mandatory in regulation in order to alert drivers to fasten their seat belt. The rate of fastening seat belts in the front seat has gone up since penalties have been applied in the road traffic laws. On the other hand, a growing number of casualties are reported for rear seat passengers who have not fastened their seat belt. Considering this situation, JNCAP has carried out seat belt reminder performance evaluation also on rear seats.

In recent result of JNCAP, a vehicle equipped with a rear seat belt reminder system achieved high points.

## Overall safety performance evaluation

Performance evaluations as described above are published with five-star ratings which are easy for the general public to understand. And it is characteristic of JNCAP that Passenger Protection performance and Pedestrian Protection performance are equally evaluated. Each part has 100 points as full marks, so Pedestrian Protection performance has more significant weight compared with other NCAPs in the world.

## Other evaluation

JNCAP has also carried out other evaluations such as seat belt usability evaluation and brake performance evaluation. In 2013, 16 models were evaluated at JNCAP including reverse tests as mentioned above.

## New activity of JNCAP

### Introduction of performance evaluation for Advanced Safety Technology

The performance evaluation for Advanced Safety Technology, Autonomous Emergency Braking System (AEBS) and Lane Departure Warning System (LDWS) are on schedule from 2016. The AEBS performance evaluation test procedure refers to Euro NCAP procedures but evaluation methods are modified with consideration of Japan's situation in road traffic crashes. For example, the speed of a tested vehicle is defined up to 60 km/h which covers most road accidents and a function of Autonomous Braking could be evaluated equally with a function of alert for the driver.

LDWS performance evaluation refers to US-NCAP and is modified with the consideration of Japan's situation, too.

As for the characteristics of JNCAP, the result of evaluation for Advanced Safety Technology would be published separately from existing JNCAP results of overall safety performance evaluation; and a point of performance evaluation for each system (now only AEBS and LDWS in 2016) could be integrated. Using integrated scores, we

are aiming to promote a diffusion of Advanced Safety Technology of the first stage. In addition, we had made a road map for Performance evaluation for Advanced Safety Technology to introduce any other technology and expand with integrated scores. (See Figure 4)

## Promoting JNCAP activities

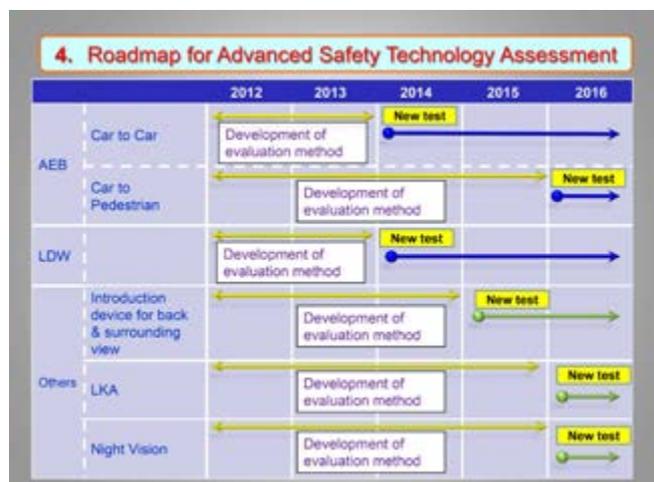
NASVA have been working on public relations in order to gain more recognition of JNCAP activities for its practical use. This includes an open day for collision testing and supporting rescue drills by providing post-crash vehicles. It is effective for rescue teams to use the latest vehicle or hybrid car mounted high voltage battery.

## Conclusion

Over the next few years, JNCAP will focus on evaluation for advanced safety technology i.e. AEBS and LDWS. Manufacturers are developing autonomous technology. It takes time to get these systems to perform reliably. We therefore think it will take significant time before we see fully autonomous driving systems. For the time being, there will still be many road accidents so continuous effort to improve road traffic safety is crucial. NCAP's unique measures generate great power by co-operating with government, academics, industry and the public. Henceforth JNCAP should be implemented even more with the leadership of government in Japan. And in spite of some difficulties because of the necessity to reflect regional road futures and road accidents, it could be useful to see more co-operation with NCAPs globally - especially exchanging their information and experience. Between Australasian NCAP and Japan NCAP, this information sharing could be particularly meaningful because many of the same vehicles are being used in each road traffic area.

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# Overall rating system in KNCAP and the further enhancement roadmap

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## Introduction

The main aims of the New Car Assessment Program in Korea (KNCAP) established by the Ministry of Land, Infrastructure and Transport in 1999 are to provide information on vehicle safety performances; develop competition in vehicle categories with a star rating system; as well as providing safety scores to the consumer who intends to buy a new vehicle in order to help in buying a safer vehicle. The second intention is a driving force to promote the auto makers to build the best and safest vehicles that they can. These philosophies are believed to be one of the most effective vehicle safety policies in reducing the social cost and physical (lives and property) loss in the event of traffic accidents.

Currently, the national target for reduction of fatality is 30% during the five year period (2013-2017). To achieve the national target, KNCAP, the most effective tool for enhancing vehicle safety, should be enhanced and expanded. From statistical analysis of traffic accidents, it must be determined what types or patterns of accident and severe casualties most frequently occurred on the roads. With weighting factors in terms of national safety priorities, KNCAP can be enhanced to reflect the real road vehicle safety problems.

In 2011, the United Nations launched the UN Decade of Action for Road Safety (2011-2020) Plan. Improved vehicle safety is a one of five main pillars of the Global Plan for the Decade in reducing 50% of traffic related fatalities. The Plan recommends that UN Member States apply minimum crash tests standards and establish regional NCAPs. Also, the United Nation's General Assembly adopted a resolution on road safety which encourages "the implementation of new car assessment programmes in all regions of the world

in order to foster availability of consumer information about the safety performance of motor vehicles."

In road safety, the first step in the process is identifying significant safety areas and the mechanisms of accidents and/or injuries that govern the problem. Korea also prescribed as law the establishment of a five year national strategic plan to reduce traffic accidents. Currently, it is now in the second phase of the plan (2013-2017), targeting reduction of 30% of traffic fatalities during the five year period. To meet the national target, KNCAP, the most effective tool for enhancing vehicle safety, should be enhanced and expanded. From statistical analysis of traffic accidents, it must be determined what types or patterns of accident and severe casualties most frequently occurred on the roads. With weighting factors in terms of safety priorities, KNCAP can be enhanced to reflect the real road vehicle safety problems.

## Statistics and analysis of traffic accidents

### Traffic accident statistics

From an economic point of view, in the area of automotive production, Korea is now one of the top ten countries globally including: seventh ranking in exports, tenth in trade volume and fifth in vehicle production volume. However, according to global statistics in road safety, Korea was ranked 29th of 32 OECD countries in 2011. The number of deaths per 100,000 populations was 10.5 (OECD average 6.8) persons and the number of deaths per 10,000 vehicles was 2.4 (OECD average 1.2) persons.

From police reports which counted only injuries involved in road traffic accidents in 2012, the total number of accidents were 223,656 cases, 5,392 deaths (within 30 days), and 344,565 injured persons were reported. As shown in Figure 1, fatalities involved accident patterns which can be classified by 1,997 deaths from car-to-pedestrian accidents (37.0%), 2,156 deaths from car-to-car accidents (40.0%) and 1,256 deaths from single vehicle involved accidents (23.3%); and rail crossing type accidents involved three deaths in 2012. According to classification by types of road user, fatality can be categorised with 2,027 (37.6%)

deaths from pedestrians, 2,090 (38.8%) deaths from vehicle occupants, 908 (16.8%) deaths from motorcyclists, 286 (5.3%) from bicyclists, and 81 (1.5%) deaths from other types of road users as shown in Figure 2. The passenger vehicle involved 49.7% of all fatal accidents while trucks were 22.8% and 12.1% were represented by motorcycles.

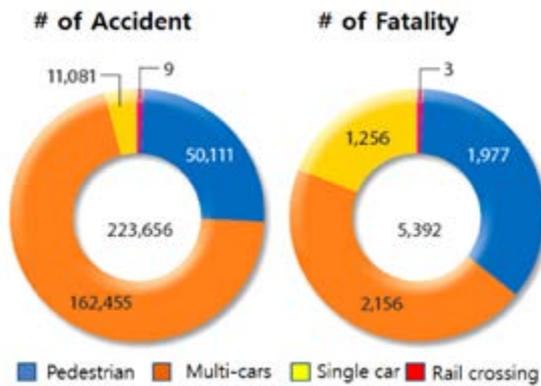


Figure 1. Fatalities by accident types in 2012

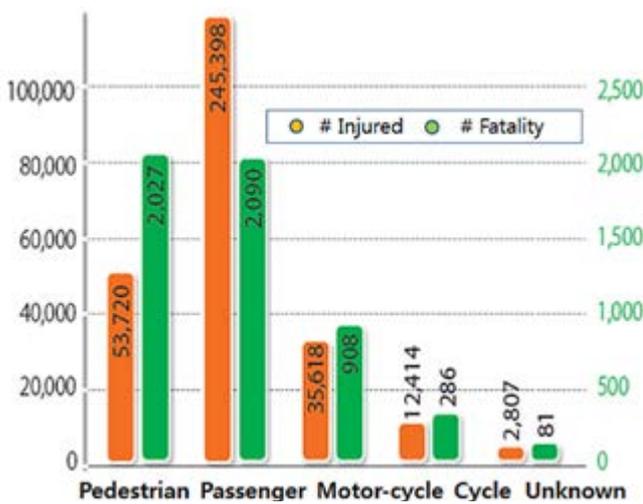


Figure 2. Fatalities by road users in 2012

According to the detailed analysis, head-on collision was shown to have the most fatal severity rates. The fatality rate was 4.6 deaths out of 100 accident cases. While side collision showed 1.1 deaths ratio, rear collision while driving was 1.3 deaths ratio, rear collision while parking was 1.1 deaths ratio as shown in Figure 3. It was also noticed that the ratio of female drivers involved in accidents and the fatality of female drivers was continuously increased. In 2012, 16.6% of traffic accidents were caused by female drivers. The female driver's fatality rate has reached up to 9.3%. (See Figure 4).

One of the most serious road traffic safety issues now faced in Korea is the dramatically increasing fatality rates of elderly drivers. In 2012, the number of accidents which were caused by elderly drivers were 13,583 cases (6.1%) and 605 elderly drivers were killed (11.2%). The fatality

ratio (4.5) was 1.7 times higher than overall fatality ratios (2.4). From the injured accident analysis, 46.3% of all injured accidents were neck injury by rear collision type accidents. The child injury involved accident rate was 4.5%.

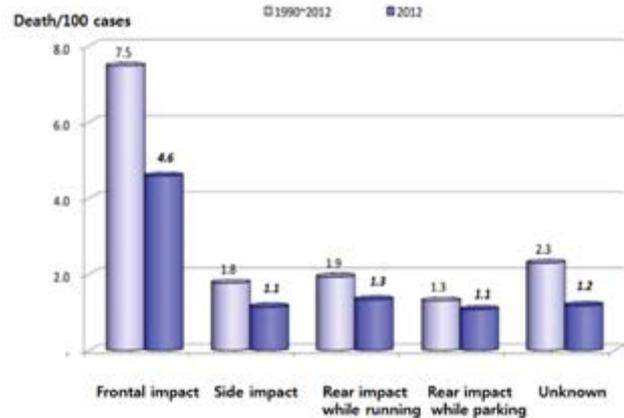


Figure 3. Fatal severity ratio in car-to-car accident in 2012

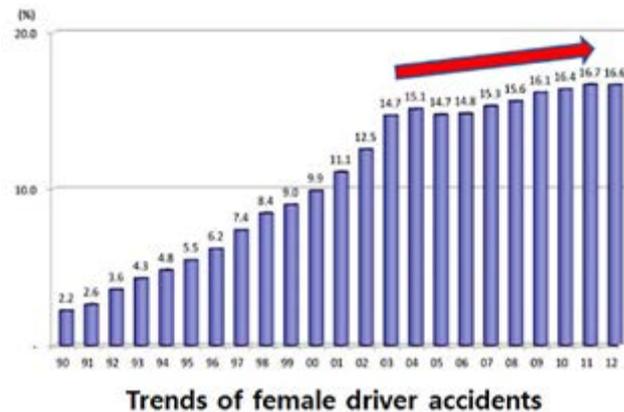


Figure 4. Trends of female drivers involved in accidents

### Statistical analysis of traffic accidents

Results from the statistical analysis of the 2012 road traffic accident database can be characterised as follows:

- Car-to-car accident is the most frequent type of collision and severity ratios differ from the type of accidents.
- Higher pedestrian fatality is still a serious problem.
- The number of female drivers involved in accident and fatalities are continuously increasing.
- The number of elderly drivers involved in accidents, deaths and injury are rapidly increasing.
- WAD related injury is the most dominant type of injury pattern.
- The number of injured children in vehicles can't be ignored.

## Enhancement of Korean New Car Assessment Program

MLIT has been conducted for a total 118 vehicles (112 passenger cars, four small buses, two trucks) during 1999 - 2013 according to four safety fields: vehicle crash safety; pedestrian protection; rollover prevention and braking performance; and vehicle active safety.

In 2013, the overall rating system in KNCAP has been launched to help the consumer's to understand excellence of safety performance categorised by five different Class systems (1st Class, 2nd Class, 3rd Class, 4th Class, and 5th Class). Since 1999, KNCAP started only three vehicles were tested in the full wrap frontal impact test, but it has been continuously expanded and enhanced to nine different test protocols as shown in Figure 5.



Figure 5. History of KNCAP and expansions

### Overall rating system

KNCAP conducts nine different test protocols including the frontal crash test, side crash test, pedestrian head and leg tests. All nine test results of each individual vehicle will be integrated and overall points calculated (maximum 100 points). With the final points, each vehicle's safety rating can be determined between Class 1 to Class 5 ranges. The test methods and assessment criteria are as follows:

#### A. Assessment fields (four categories)

- Vehicle crash safety: full wrap frontal impact test, offset frontal impact test, side impact test, side pole impact test, and rear impact sled test.
- Pedestrian protection: pedestrian head and leg impact test.
- Rollover prevention and braking performance: braking tests, rollover stability test.
- Vehicle active safety: seatbelt reminder test.

#### B. Evaluation

- Add points of each category's test results and convert into a percentage.
- Multiply converted percentage by weighting factors (see Table 1).
- Classified Class grade based on final points (see Table 2).
- Check minimum required percentages in both vehicle crash safety and pedestrian protection (see Figure 6).

Table 1: Weighing factor for overall rating system

Assessment field	Weighting factor (%)
Vehicle Crash Safety	65
Pedestrian Protection	25
Rollover prevention and Braking performance	10

Table 2: Overall rating criteria and minimum required points

Overall Rating Criteria		Minimum required points		
Class	2013(pts)	Class	Vehicle Crash Safety (%)	Pedestrian Protection (%)
1	83.1~	1	90.1~	50.1~
2	80.1~83.0	2	87.1~90.0	40.1~50.0
3	77.1~80.0	3	84.1~87.0	35.1~40.0
4	74.1~77.0	4	81.1~84.0	30.1~35.0
5	~74.0	5	~81.0	~30.0

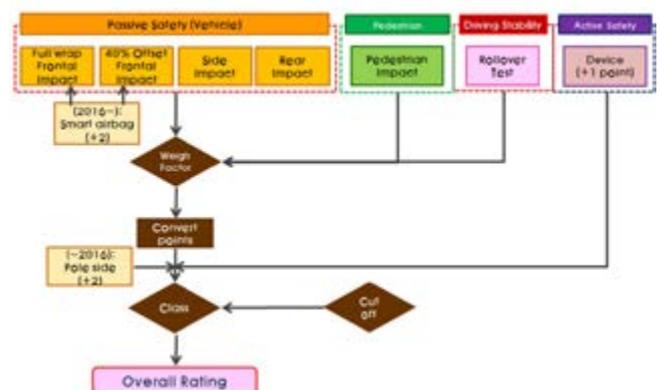


Figure 6. Overall rating process in KNCAP (2013-)

#### C. Labelling and promotions

It is very important that test results are made easier and more understandable to consumers. In KNCAP, the assessment of individual vehicles consists of overall class ranking and each four category grading systems. As shown

in Figure 7, each assessment result can be visualised to improve clarity. The detailed data is available to the public through websites [www.car.go.kr](http://www.car.go.kr) or [www.ts2020.kr](http://www.ts2020.kr) or mobile phone application [m.car.go.kr / kncap](http://m.car.go.kr/kncap).



Figure 7. Labelling of overall rating for each vehicle

### Effectiveness of KNCAP

Historically governments and research organisations have used the traditional statistical approach to assess benefits of safety programs such as NCAP or safety devices using in-depth crash data which normally allows a more detailed level of analysis. In Korea, publicly available accident data is only published through police reports rather than allowing direct access to the detailed raw database. Current Korean in-depth accident databases for research purposes have a limited number of cases and are still in the early stages. In this study, as an alternative, the improvement of vehicle safety in terms of KNCAP rating was compared with tested vehicles in chronological order.

For frontal crash tests, the average combined serious injury risk probability (AIS 4+) for the first three years of vehicle testing (1999-2001) was 21.6%. Safety performances have been significantly improved in the last three years (2011-2013) - the average  $P_{comb}$  value was decreased to 15.1%. In results from side crash test analysis, the probability of serious injury (AIS 3+) was 11.3% in 2003. In 2013, the value was dramatically dropped to 2.0% as shown in Figure 8. In the Side pole impact case, potential serious injuries (AIS 3+) were 95.6% in 2009 and also dropped to 8.9% in 2013 (see Figure 9). The Side pole crash test was added in KNCAP protocol as an optional test which manufacturers can choose to get a maximum additional two points from this extra test. Within four years, even though the side pole test was initiated as an optional test, most vehicles have recently been equipped with side curtain airbag as a standard option. In addition, it was clearly proven that a side curtain airbag is a most effective safety device to protect occupants from the side pole collision type accidents.

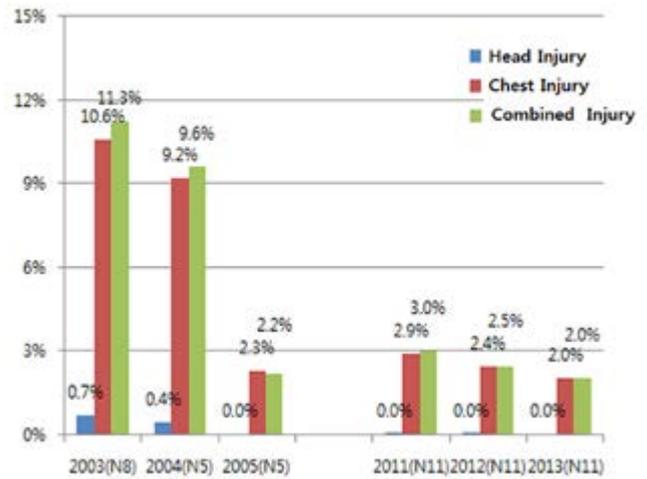


Figure 8. Improvement of side crash safety

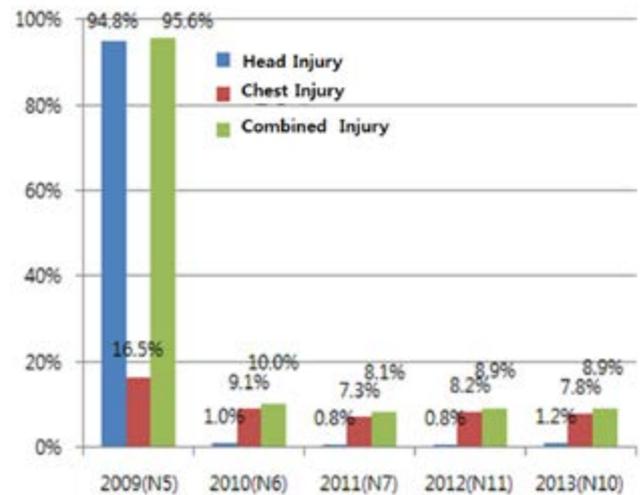


Figure 9. Improvement of side pole crash safety

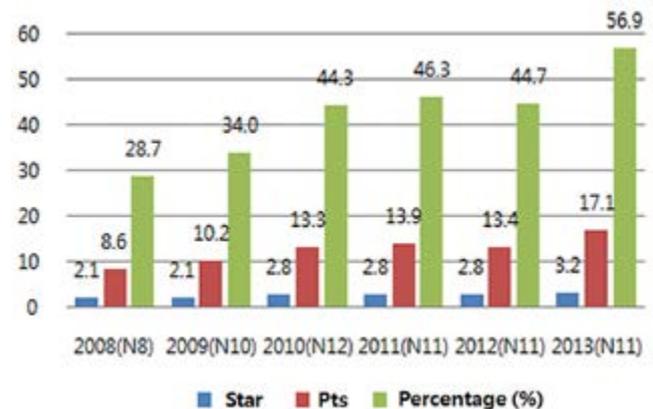


Figure 10. Improvement of pedestrian safety

Pedestrian safety in 2013 compared to 2008 was improved nearly twice as much (see Figure 10). However, pedestrian accidents and higher fatality rates are big issues which leave plenty of room for improvements in KNCAP.

## KNCAP Roadmap (draft)

In Korea, KNCAP has been established to evaluate vehicle safety performance to reduce the number of traffic deaths, serious injuries as well as the number of accidents. The KNCAP roadmap must be reflected in national traffic accident statistics. Also more care is needed for vulnerable

road users such as children, women, the elderly and pedestrians. The draft KNCAP roadmap emphasises protection of vulnerable rear seat occupants and promotion of active safety technology.

Plans include in 2014: Active pedestrian protection test; and after 2017: enhancing side impact safety, seatbelt reminder (two-row seats expand), speed limiter, female drivers, children (6 years old, 10 years old) in front and side impacts, automatic cruise control, drowsiness prevention, blind spot detection, monitoring drunk driving, lane-keeping support and automatic emergency braking systems.

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# The First four years of Latin NCAP: short time, great progress in the LAC market

by *Alejandro Furas*

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Since 2010 Latin NCAP has been testing the most popular vehicle models available in Latin America. It was demonstrated that Latin America's best selling models are 20 years behind Europe, US, Japan and Australia in terms of vehicle safety. After four years and more than 35 models tested, finally the region is beginning to have popular cars offering the highest safety levels.

The most basic equipped versions, which are the ones selected by Latin NCAP, showed that the absence of airbags exposed the passenger dummies to serious injuries. The structural performance of the passengers' compartment was weak to poor in the best selling models of Latin America. That meant that at least 450,000 new cars every year were sold with 1 and 0 star safety levels.

Latin NCAP has also had to deal since its beginning with the lack of technical regulations for vehicle safety performance under frontal or side crash situations. This situation offered Latin NCAP an extra challenge still under development.

Latin NCAP tested cars - even with airbags - being sold in the region and they still offered low protection levels to its occupants due to weak structures. One powerful result that can illustrate the risks of an unstable structure even with two airbags and pretensioners is the JAC J3 that scored only one star in adult occupant safety.

Some governments in the region are requiring airbags by law and the previous example shows clearly that airbags alone may not solve the problem and that a performance requirement is needed. Some countries in the region are focusing on the introduction of performance criteria regulations.

Cars with no airbags showed high risk of life threatening injuries for passengers. In cases where the same model was tested with and without airbags, the benefit of the airbags was clear in the result bringing some models from one to three stars, and another from one to two stars. This also shows that there is room for improvement in some cases with not very dramatic changes needed to make the cars perform better in the test.

Latin NCAP also compared models tested in our program to the same models tested by other NCAPs such as Euro NCAP. There is a clear difference in safety equipment of the same models; like less airbags, no ABS or no ESC for example. But we have seen cases where the structures of two same looking models behave in a very different way. Examples of that are the Nissan March compared to the Nissan Micra, or Renault Sandero and Dacia Sandero. In those cases the Latin NCAP structure was rated as unstable and intrusions were higher as well.

Latin NCAP received comments from consumers claiming that the airbag versions of the models tested are much more expensive than the basic, non-airbag version. In some cases the consumer must pay from 18% to 33% on top of the basic price to get just double frontal airbags. In some cases this is explained by the “package” that offers the manufacturer matching airbags with other non-safety related items like Bluetooth or alloy wheels.

In one sample case of the same European model but different structural behaviour, having the Latin NCAP model with no airbags, but the European model six airbags, ABS and ESC the price difference at the same time between those cars (one sold in Europe and the other sold in Latin America) was less than 1000 Euros. However these price differences are strongly linked to the local taxes. Cars in Latin America are as or more expensive than in Europe and they offer a lower level of occupant protection. Some consumers are wondering why this is happening and how it can be fixed.

Latin NCAP compared a model to the identical car offered in Europe: Nissan March (Latin America tested by Latin NCAP) and Nissan Micra (Europe tested by Euro NCAP).

Both cars were compared only in the frontal crash test. Both have double frontal airbag.

A post-test technical comparison showed differences in the structures of both cars which explained differences in the car’s occupant protection performance.

In order to make a more global analysis, in June 2012 Latin NCAP explored the market of this car in terms of prices and equipment and found the following results:

		Values in €URO\$					
Structure	Icon	ARG	BRA	COL	URU	GER	FRA
March		N/A	N/A	10,469	13,397	N/A	N/A
			+3,416	33%	18%	+2,402	
March		13,420	9,900	13,885	15,800	N/A	N/A
Micra		N/A	N/A	N/A	N/A	10,840	10,590

This table shows that to get a double airbag in this car in markets like Uruguay and Colombia the consumer must pay more than 18% more than the basic price which means more than 2400 Euros, but in Colombia this increase goes up to 33% which means more than 3400 Euros.

Compare the prices of the Latin American car, which has a weaker structure and no more than two airbags versus the European model which cannot be purchased with less than two front airbags, two side airbags, two curtain airbags, ABS and ESC. In Germany this model is less expensive than a less safe Latin American car in Argentina, Colombia or Uruguay and less than 1000 Euros more expensive than in Brazil.

The reason for these price differences can come from taxes as well as from higher prices from the manufacturers to sell the car in Latin America. For any of these reasons, Latin American consumers of small cars - that in general earn lower wages than the European population per month - are forced to pay much more for a much less safe car. Manufacturers and the Government should review this fact in order to balance this situation to enable safer cars to be available in Latin America at lower prices.

Latin NCAP also analysed the case of comparing the Dacia Sadero (Europe) and Renault Sandero (Latin America). The comparison here focuses on the structure of both cars that look the same but are built in different plants.



*Sandero: Comparing the same model from different plants, the difference in bodyshell stability can be clearly noticed.*

Until Phase 3 of Latin NCAP testing in 2012, the models that could offer a four star level of safety to their occupants were large and expensive models. However, the Toyota Etios showed that a car from the small most competitive market in the region can offer four stars in adult occupant safety and be sold for a price close to the 10,000 Euros in Brazil as well as being locally produced.

After the latest introduction of protocol changes in 2013, adding requirements to reach the five star score, some manufacturers reacted and begun to offer five-star models. At the early stages all models with five stars were expensive models until December 2013, Volkswagen introduced the VW up! made in Brazil. A bit different than the European version with a larger fuel tank, longer trunk, taller suspension, larger wheels and metal trunk door, the up! was assessed and reached five stars in adult occupant protection and four stars in child occupant protection. The up! is the first car in the Latin NCAP market from the compact segment reaching the five star result.

Latin America is composed of emerging economies. Unfortunately some manufacturers present to this market “low cost cars” that offer low to no safety levels. Recently Latin NCAP presented two price comparisons that showed

that the so called “low cost” models other than offering very low safety levels do not seem to be so “low cost” compared to European models with high basic safety.

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## The CITI Project - Australia’s first Cooperative Intelligent Transport System Test Facility for safety applications

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### What are Cooperative Intelligent Transport Systems and how will they benefit Australians?

Cooperative Intelligent Transport System (CITS) is the term generally defined as a form of Intelligent Transport in which information is shared amongst vehicles or between vehicles and roadside infrastructure such as traffic signals.

Sophisticated CITS applications have been developed that increase the “time horizon” as well as the quality and reliability of information available to the drivers about their immediate environment, other vehicles and road users. This has the potential to greatly improve road safety, reduce greenhouse gases and improve network efficiency.

Whilst a number of communication platforms such as the 3G or 4G mobile phone network can be used to carry communications between vehicles and roadside units, specific dedicated short range radio channels in the 5.9 GHz area of the radio spectrum are planned to be used by most major jurisdictions overseas. In Australia, use of the 5.9 GHz band is currently embargoed and the Australian Communications and Media Authority (ACMA) has recognised its future potential use for CITS, however a final determination on the use of the spectrum and its licensing is yet to be made (NTC 2012).

### The road safety benefits of Cooperative ITS

The United States Department of Transport in their white paper on CITS has estimated that up to 82 percent of all crashes by unimpaired drivers could potentially be addressed by vehicle to vehicle (V2V) technology. If V2V were in place, another 16 percent of crashes could potentially be addressed by vehicle to infrastructure (V2I) technology.

Austrroads conducted a study into the potential road safety benefits of vehicle to vehicle dedicated short range communications (DSRC) in September 2011. The report found that the current total of approximately 29,000 annual serious casualties could be reduced to between 18,500 and 21,500; a reduction of 25-35 per cent (Austrroads 2012). A serious casualty includes road users that are killed or seriously injured as a result of a road crash.

### Other benefits of Cooperative ITS

The National Transport Commission also reports that overseas studies indicate that significant environmental and productivity benefits may also result from the deployment of CITS applications.

### The CITI project

#### Location

The CITI project is proposed to cover a 42 km length of road that connects the Hume Highway in Sydney’s South West to Port Kembla situated two kilometres south of Wollongong Central Business District.

Heavy vehicles were involved but were not necessarily at fault in 69% of the fatal crashes recorded on the proposed route in which 13 people were killed (Over a three year period up to 30 September 2011). Significant engineering safety works have been carried out along the Picton Road section of the route since 2011, including road widening and flexible crash barrier deployment.

#### Type and number of dedicated short range communication devices within the project

The first stage of the project proposes to fit in-vehicle dedicated short range communication (DSRC) transceivers

into at least 30 trucks that regularly travel the planned route. In addition, at least one signalised intersection will be equipped with DSRC roadside units which will communicate with the trial vehicles. A 40 km/h truck and bus speed zone warning system is also planned for installation at the top of Mt Ousley to alert drivers about to descend the very steep (up to 12 percent downhill gradient) south bound section of the road.

### Types of information provided to drivers in the CITI project

The Austroads report on the evaluation of road safety benefits lists 18 safety related DSRC applications related to V2I communication and a further 14 through V2V systems. These applications were then evaluated for their potential influence on serious casualty numbers. The most effective DSRC applications according to the 2011 Austroads report are: intersection collision warning (V2I application); left/Right turn assistance (V2I application); cooperative collision avoidance warning (V2V application); cooperative forward collision avoidance warning (V2V application); and pre-crash sensing (V2V application).

It is expected that the CITI project will eventually include all of the most effective applications identified by Austroads with the exception of pre-crash sensing which would need to be built into the vehicle by the original manufacturer.

In addition to the applications previously described, the project will also deploy within the first stage of operation: electronic brake light; heavy Vehicle Speed limit zone information; adverse weather alerts; and limited traffic signal phase and timing information.

### Funding model

The funding model for this project is unique with just over \$1.4 million of funding for the initial project having been sourced from the NSW Government through the NSW Road Safety Program and the Federal Government's Heavy Vehicle Safety Productivity Program under the Nation Building Program respectively. A contribution from National ICT Australia (NICTA) of \$250,000 was also received and will come primarily in the form of a Project Manager.

## Conclusion

Cooperative Intelligent Transport Systems offer the promise of increased road safety, improved efficiencies and substantial environmental benefits. However, no semi-permanent facility was available in Australia to test the validity of these claims.

The CITI project will be Australia's first semi-permanent test facility for connected intelligent transport systems. The project also differs from others around the world in that it is planned to be available to researchers of Intelligent Transport Systems for up to five years, whereas most other demonstration sites have only been established for a period of up to 18 months.

The CITI project will not only be a trial of Cooperative Intelligent Transport Systems Technologies but will also be a platform that road safety researchers and practitioners can use to evaluate and develop what may become known as the road safety 'silver bullets' of the 21st Century.

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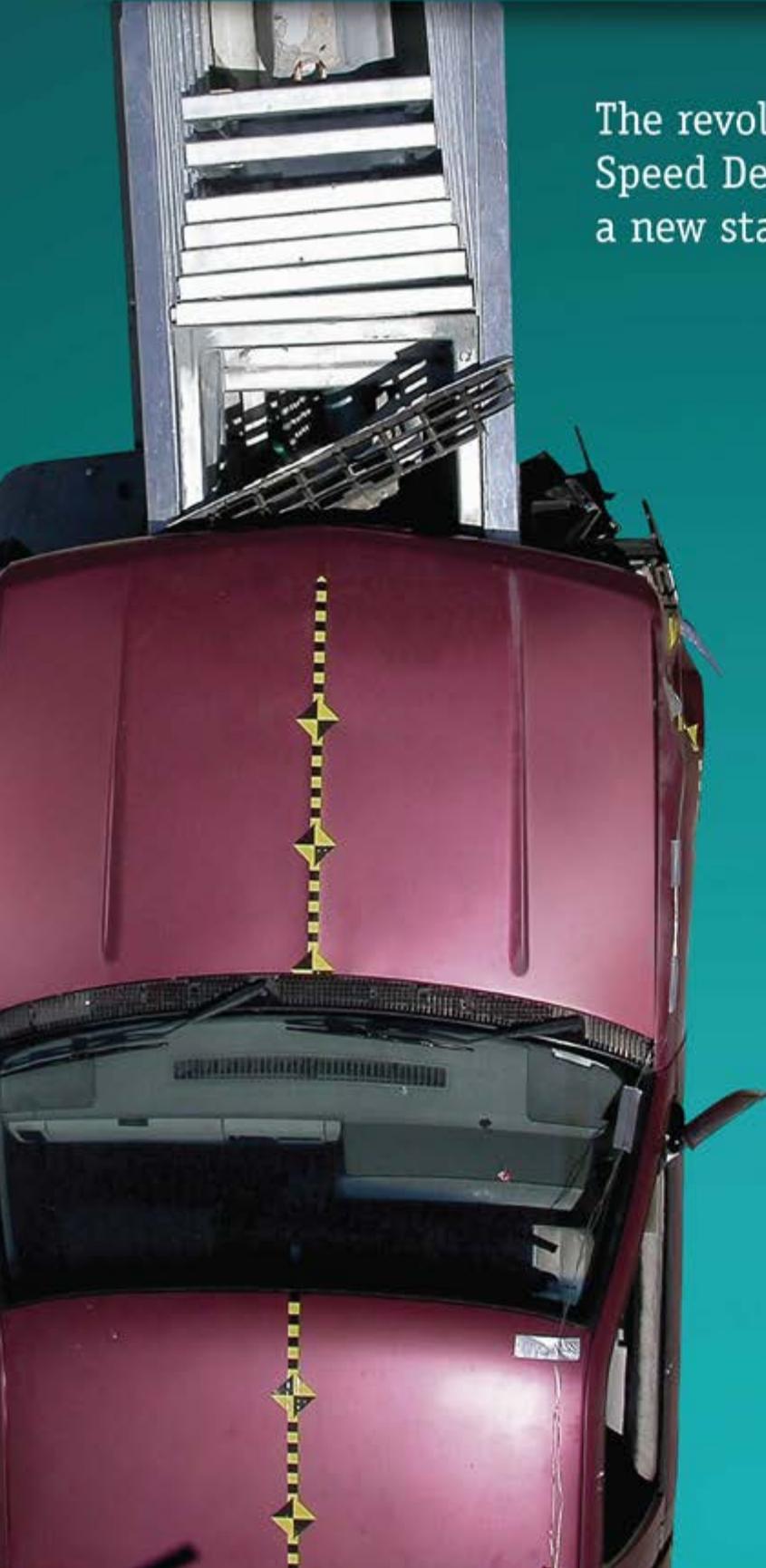
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