



Journal of the Australasian College of Road Safety

Formerly RoadWise – Australia's First Road Safety Journal



Special Issue: Heavy vehicles

Peer-reviewed papers

- Prevalence of affective states in Australian truck and train drivers
- Safety culture and speeding in the Australian heavy vehicle industry
- A road safety risk prediction methodology for low volume rural roads
- Laser ablated removable car seat covers for reliable deployment of side airbags

Contributed articles

- Heavy vehicle driver fatigue: evidence-based policy making
- Driving heavy vehicle safety through technology: challenges, results and lessons learned at Toll Group: A contextual overview
- In-truck cameras at Toll NQX
- Driver State Sensing (DSS) machines at Toll Resources and Government Logistics
- Road safety: a reliable investment for every profitable heavy vehicle business

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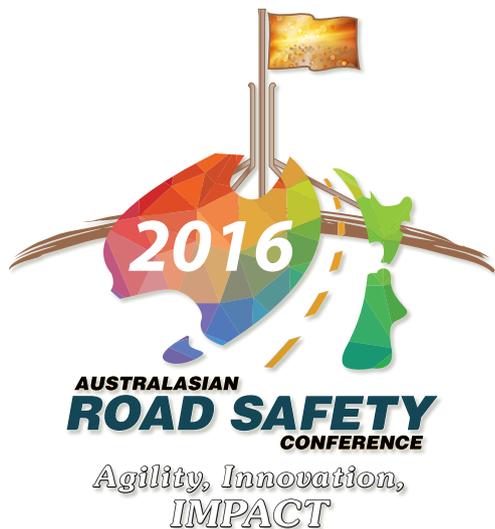
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On behalf of the Australasian College of Road Safety, Austroads and The George Institute for Global Health, we are delighted to invite you to be part of the 2016 Australasian Road Safety Conference (ARSC2016) to be held at the National Convention Centre, Canberra, Australia from Tuesday 6 – Thursday 8 September 2016. We expect over **600 delegates** will join us again this year in support of our efforts to reduce road trauma, and we encourage you to join us!

As part of the delegate experience in the lovely city of Canberra during Spring 2016, included in the conference registration fee delegates will attend conference functions at two of Australia's iconic national landmarks – the **Welcome Reception to be held in Anzac Hall at the Australian War Memorial**, and the **Conference Gala Dinner in the Great Hall at Parliament House**.

With a theme of "**Agility, Innovation, IMPACT**", ARSC2016 will showcase our regions' outstanding researchers and practitioners spanning the many and diverse road safety issues identified in the United Nations Decade of Action for Road Safety: Road Safety Management, Infrastructure, Safe Vehicles, User Behaviour, and Post-Crash Care. Delegates will be treated to a comprehensive program showcasing the latest research, education and policing programs, policies and management strategies, latest technological developments in the field, together with national and international keynote speakers, oral and poster presentations, workshops and symposia.

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<http://australasianroadsafetyconference.com.au>



ARSC2016 will include the Australasian College of Road Safety Awards, to be presented during the Conference Dinner at Australia's Parliament House. These awards recognise and celebrate exemplary projects and people working hard across our region to save lives and reduce injuries on our roads.

Win a Trip to the USA for your road safety efforts!!!

The 2016 Australasian College of Road Safety Awards continues the tradition of recognising and celebrating our outstanding achievers in road trauma reduction.

These awards will include the following presentations:

- The prestigious Australasian College of Road Safety Fellowship Award in recognition of an outstanding contribution being made by an individual to road safety in Australasia.
- Australasia's premier road safety award recognising projects that exhibit exemplary innovation and effectiveness to save lives and prevent injuries on roads – the 3M-ACRS Diamond Road Safety Awards. Grand Prize of a trip to the USA.

- ARSC2016 Conference Awards
- Other awards as deemed appropriate by the joint hosts for 2016: ACRS, Austroads and The George Institute for Global Health.

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

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

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WHO WILL JUDGE ENTRIES?

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



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theaustralasianroadsafetyawards.com.au

Entries open 1st February 2016 and close 5pm (EST), 24th June 2016

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Cover image

Toll Group operates nearly 3000 heavy vehicles in Australia. Those vehicles travel around 300 million kilometres delivering 54 million consignments each year. Speed, fatigue and driver inattention/distraction are key policy challenges in the heavy vehicle space. Toll Group has invested in technologies of various kinds to reduce crash and incident risk including: in-vehicle cameras, driver-state sensing machines and driver simulators.

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The aim of the *Journal of the Australasian College of Road Safety* is to provide a medium for expression of views and debate on all facets of the study of road safety. Articles are accepted from a variety of disciplines, such as health and medicine, road and automotive engineering, education, law, behavioural sciences, communication, history, management, and urban and traffic planning. Interdisciplinary approaches are particularly welcome.

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

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From the President



Dear ACRS members,

Heavy vehicle safety is a key factor in the safe systems approach to reducing road trauma. This issue provides some specialist comments on the subject.

Our roads provide the necessary network for the distribution of freight to ensure our economy works. Heavy vehicles and trucks,

are along with cars and bikes being equipped with many new technologies to improve their productivity and also their safe operation.

Trucks are workplaces. While we are increasingly realising that many cars are workplaces, trucks have always been workplaces, sharing roads with other workers and of course recreational users.

Sharing is a complex process, and our views of the process are built on a wide range of personal experiences relating to the road infrastructure; and a historical understanding of the trucks on the roads.

New trucks, new management, new approaches to regulations are already in place and the new “disruptive” technologies have been introduced into some truck fleets in areas such as data and scheduling management; collision avoidance; lane keeping; fatigue recognition; and load management, to name a few.

In the last journal I noted that while some of these technologies were already mandated in Europe, Australasia had yet to determine how to encourage early implementation. Trucks traditionally have a long service life; trucks introduced into the fleet this year can expect to be still operating on our roads in 30 years’ time. So any delays in the introduction of proven safety technologies will have long tail consequences in our commitment to the safe system Vision Zero goals.

The issue of course is not limited to regulation. Companies, drivers, researchers, developers and financiers as well as road owners and builders need to recognise and commit to those goals.

*Lauchlan McIntosh AM FACRS
ACRS President*

Diary

10 March 2016

TMAA National Traffic Management Conference
Sydney, New South Wales
<http://conference.tmaa.asn.au/>

17-19 May 2016

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

9 - 10 June 2016

7th International ESAR Conference “Expert Symposium on Accident Research”
Hannover, Germany
<http://www.esar-hannover.de/?Index>

2 - 5 August

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

6-8 September 2016

Australasian Road Safety Conference (ARSC 2016)
National Convention Centre, Canberra
<http://australasianroadsafetyconference.com.au>

18 - 21 September 2016

Safety 2016: 12th World Conference on Injury Prevention and Safety Promotion
Tampere, Finland
<https://www.thl.fi/en/web/injury-prevention/safety-2016>

10 - 14 October 2016

23rd ITS World Congress
Melbourne, Victoria
<http://www.itsworldcongress2016.com/>

16 - 19 October 2016

T2016: 21st International Council on Alcohol, Drugs and Traffic Safety (ICADTS) Conference
Gramado, Brazil
<http://www.t2016.org/>

28 - 30 November, 2016

13th International symposium and accompanying exhibition on sophisticated car safety systems, Mannheim, Germany
http://www.ict.fraunhofer.de/content/dam/ict/de/documents/veranstaltungen/2016/Airbag_Call_for_Papers_2016.pdf

NZ Transport Agency promotes safe and efficient movement of freight

by Harry Wilson
Freight Portfolio Director
NZ Transport Agency



With around 70 per cent of New Zealand's freight transported by road, the New Zealand Transport Agency is committed to doing all it can to ensure that both people and goods are moved safely and efficiently on the country's land transport network.

Over the past several years the Transport Agency has worked hard to create an environment which encourages freight operators to take responsibility for their own compliance, while ensuring there are safeguards in identify operators who do not.

In 2010 a change to the Vehicle Dimension and Mass rule allowed larger and/or heavier trucks to operate on New Zealand roads under permit. The Transport Agency has worked with the industry to enable them to adopt these High Productivity Motor Vehicles (HPMV's), where it is appropriate to do so. HPMV's are heavier and/or longer trucks which will achieve greater freight efficiency; enabling a 14 to 20 percent decrease in truck trips. HPMV's also provide safety benefits, as fewer trips reduce the exposure of vehicles to crash risk. These newer vehicles have more advanced safety features such as anti-skid braking systems and electronic stability control than the older trucks they are replacing.

At the Transport Agency we realise that improving safety in the freight industry is not something that we can do solely through enforcement. We are constantly working to foster a regulatory environment that recognises safe operators, allowing them to get on with their business while providing appropriate penalties for those who believe that safety is not a priority. We have a nationwide Commercial Transport team who work closely with the heavy vehicle industry to help them achieve a safer operating environment through

areas such as vehicle maintenance and driver management.

Earlier this year we implemented operator safety checks for HPMV permits, looking at the operator's record of compliance along with any relevant traffic offences and permit breaches to determine whether there is a safety risk in granting a permit. If there are safety concerns the operator may receive a limited permit with conditions, or if the check reveals serious safety concerns the application may be denied.

We're also working with our sector partners on implementing Safer Journeys: the Government's strategy to guide improvements in road safety. The strategy envisions a safe road system increasingly free of death and serious injury and introduces the Safe System approach to New Zealand.

This approach represents a fundamental shift in the way we think about road safety. This work covers all traffic on New Zealand's roads – but there are a number of actions designed to significantly improve the safety of heavy vehicles, including trucks. Our work is based around four key areas; safe roads and roadsides, safe speeds, safe road use and safe vehicles. More information on this and other initiatives can be found at: <http://www.saferjourneys.govt.nz/>

The support of the freight industry is important in striving to create a land transport system that is as safe and efficient as possible. In addition to the tragedy of death and serious injury from truck crashes, the vehicle damage, product loss and supply chain disruption costs the industry and the economy millions of dollars each year.

With New Zealand's freight task expected to grow by roughly 50 per cent over the next 30 years, creating a strategic freight network that maximises safety and efficiency is crucial for the country's prosperity.

Freight productivity and road safety: an Austroads perspective

by Nick Koukoulas
Austroads Chief Executive

Traditional definitions of freight as *cargo or loads carried for a fee by land, water, or air* provide little insight into the complexity of managing a well-functioning transport system and the value returned to the community.

The freight task in Australia has quadrupled over the past 40 years, and will almost double again in the next 20 years. Transport and logistics accounts for an estimated 14 per cent of GDP and supports employment in around a quarter of a million Australian businesses.

While the private sector is largely responsible for the actual freight task, government plays a crucial role providing and maintaining the supporting infrastructure, and ensuring policy supports community, environmental and economic needs.

Austroads - the peak organisation of Australian and New Zealand road transport agencies, plays a key role in this task. Austroads' purpose is to support our member organisations to deliver an improved Australasian road transport network. One that meets the future needs of the community, industry and economy. A road network

that is safer for all users and provides vital and reliable connections to place and people. A network that uses resources wisely and is mindful of its impact on the environment.

To succeed in this task, we undertake leading-edge road and transport research which underpins our input to policy development and published guidance on the design, construction and management of the road network and its associated infrastructure.

Austroads provides a collective approach that delivers value for money, encourages shared knowledge and drives consistency for road users.

In late 2015 Austroads released its *2016-2020 Strategic Plan*. Under the new four-year plan the six current Austroads Programs will be consolidated into three. The new Assets, Safety and Network Programs will be led by full-time Program Managers who will collaborate on research project development.

Austroads Freight Task Force

Austroads new strategic plan will link the Freight Task Force to the Network Program. The Task Force has members representing state and territory road agencies, the National Transport Commission, the National Heavy Vehicle Regulator, the Commonwealth Department of Infrastructure and Regional Development, and the Australian Local Government Association. The Task Force's objective is to improve productivity and safety in meeting the freight task and focuses on:

- improving freight access, including the safe and effective use of road, bridge and intermodal facilities
- providing technical input and analysis to support the heavy vehicle charging and investment reforms and improve freight transport productivity
- the use of higher productivity vehicles to meet the expected growth in the national freight task and;
- providing solutions to heavy vehicle access and local government issues.

The Freight Task Force is currently working towards:

- developing a policy framework to support freight safety, efficiency and productivity in an urban context - focussing on improving the understanding of urban freight logistics, the impact of freight vehicles on the community and environment, and the impact of urban planning on efficient vehicle operation, including



UN Decade of Action for Road Safety: The Half Way Point

Over 70 countries are united in the UN Decade of Action to reduce traffic crashes and the global road toll.

At its half way point, ICTTP2016 will showcase the latest research, programs, policy and developments in Australia and across the globe. Join over 300 researchers, policy-makers and practitioners from the areas of public health, law, medicine, economics, law enforcement, public policy, education, human factors, and psychology.

Register now! Program released March 2016.

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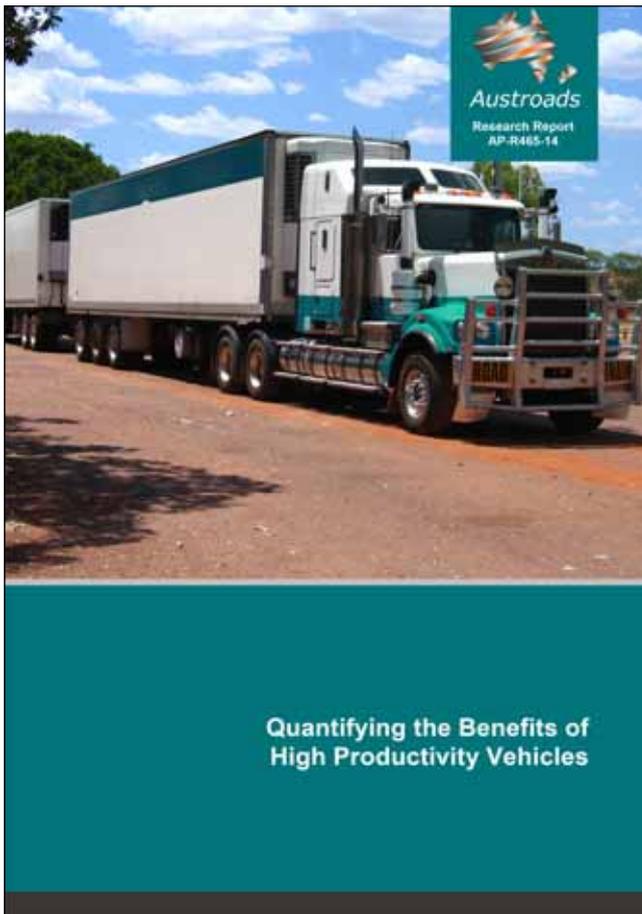
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the role of policy and regulation for urban freight vehicles. This project is due to be completed in June 2016.

- establishing optimum steer axle mass limits for road trains, with a view to accommodating the needs of the transport industry into the future. The results are due to be released in early 2016 and;
- improvements in braking performance standards for heavy vehicles to brake effectively and safely on steep declines, with work on this project due to be completed in June 2017.

Quantifying the benefits of high productivity vehicles



High productivity vehicles (HPVs) are large modular heavy vehicle combinations, assembled from standard vehicles coupled together.

In July 2014, Austroads published *Quantifying the Benefits of High Productivity Vehicles*. The study was the first of its type to create national heavy vehicle accident benchmarks for Australia and to use those benchmarks to measure the national HPV fleet accident performance rates.

The study investigated the direct and indirect benefits of HPVs across a range of measures: accidents, safety,

productivity, fuel and environmental savings against the conventional heavy vehicle fleet. The report found that the use of HPVs is poised to conservatively deliver \$12.6 billion in real benefits to Australia by 2030 through \$6.9 billion in discounted direct benefits and \$5.7 billion in indirect discounted flow-on economic benefits.

The benefits have been based on examining accident information on insured fleets to determine safety benefits; calculating the reduction of conventional trucks through the adoption of HPVs and the high capacity available to determine productivity benefits; and regarding emissions, examining the greenhouse gas, carbon dioxide emissions and the use of a dollar per tonne carbon price.

The report specifies the perceived benefits of using HPVs being derived through fatality savings, fewer accident claims, environmental benefits and lower (cargo) kilometres travelled.

Austroads Safety Program

The Safety Program's objective is to prevent death and serious injuries using a safe system approach. Its work program is determined by the Safety Task Force, which has representatives from state and territory road agencies, the National Transport Commission, the Commonwealth Department of Infrastructure and Regional Development, and the Australian Local Government Association. The comprehensive research program relates to each of the four cornerstones of the safe system: safe roads and roadsides, safe vehicles, safe speeds and safe road users.

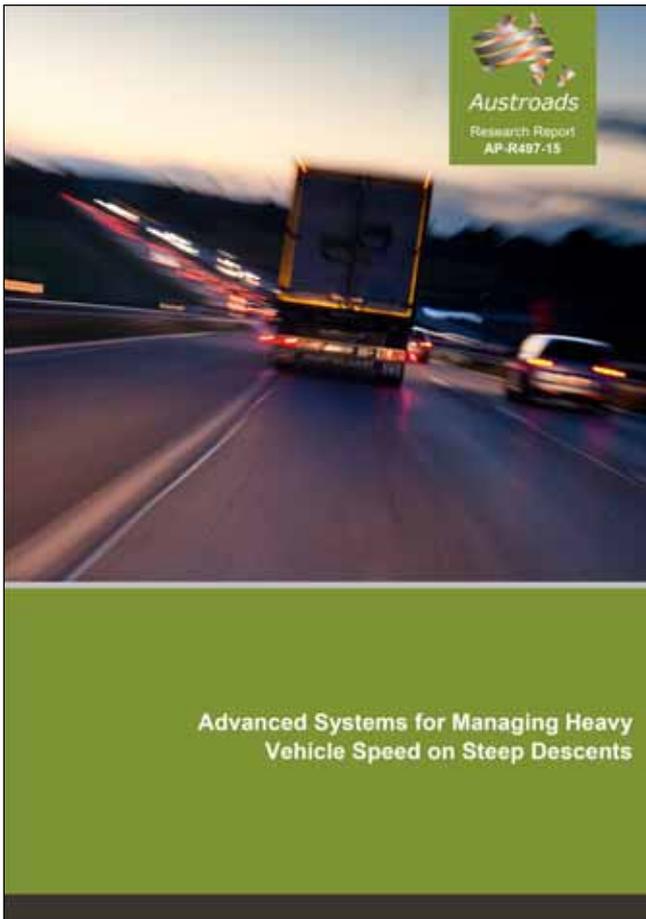
The program has been designed to support delivery of the National Road Safety Strategy 2011-2020, released in 2011. The Strategy sets a target of reducing the annual number of deaths and serious injuries on Australian roads by at least 30%. It outlines 'first steps' actions to be undertaken in the first three years of the strategy and 'future steps' actions which will be undertaken after the first review of the Strategy.

Braking on Steep Descents

The report, *Advanced Systems for Managing Heavy Vehicle Speed on Steep Descents*, was published in late 2015. It examines the availability of technical solutions that can identify heavy vehicles, their speed and configuration, and provide appropriate early warning of unsafe operation on descents.

The project determined that there are not many infrastructure-based technological systems operating and there is limited data on their effectiveness. Where the systems have been formally assessed, the assessments indicated a positive effect on driver behaviour.

Although no studies relating to the safety benefits of in-vehicle telematics or DSRC for steep descents were found, the review incorporated searches for general information on the capabilities of telematics devices. Based on general claims about the technical capabilities of in-



vehicle telematics, the review was able to identify, on an elementary level, how they may serve as a warning system to heavy vehicle drivers and possibly intervene prior to an incident.

Additionally, this study also was able to use a heavy vehicle thermal brake model to examine the effect that road grade, vehicle speed, retarder level and vehicle mass had on brake temperatures on steep downgrades. The study found that the vehicle mass and grade had the largest effect on brake temperatures, while retardation power and vehicle speeds had a lesser, but still significant effect at times.

Drink driving and the extension of alcohol interlock programs

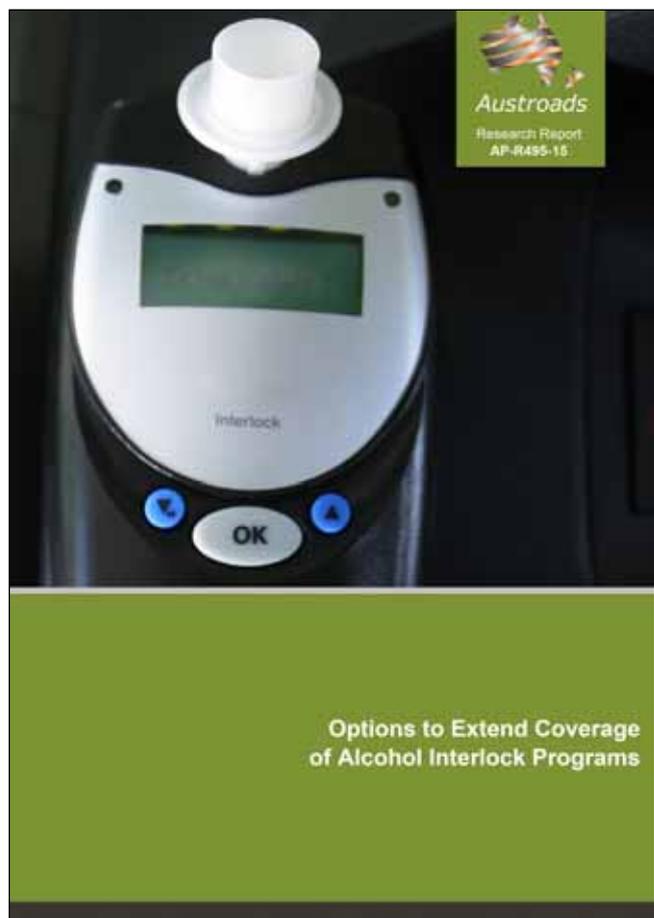
While relatively low in number, it is of concern that commercial vehicle licence holders are being detected drink-driving.

Fleet vehicles and commercial vehicles represent a substantial part of the vehicle fleet, and due to their nature have high usage and exposure rates. For large vehicles in particular, the consequences of crash-involvement are high given their poor crash compatibility with other road users due to their mass and geometry.

The Safety Task Force recently completed a project which considers options to extend the coverage of alcohol interlock programs, including into vehicle fleets and commercial vehicles.

Direct benefits to fleets and commercial vehicle operators include reduced crash risk; improved worker health; improved productivity due to fewer workdays lost due to damaged vehicles and injured workers; improved asset management; potential insurance savings; and a mechanism for meeting statutory obligations to provide a safe workplace. These benefits can be viewed in the context of both a corporate social responsibility perspective and an occupational health and safety perspective. In practical terms, the fitment of any driver monitoring system can reduce offences; promote a safety oriented culture; and reduce financial impacts of crashes, injury and illness. Acceptability would be increased if there was no requirement for rolling re-tests.

Despite these benefits, device cost, the potential need for multiple handsets, a high volume and associated cost of disposable mouthpieces, the purported frequency of recalibration and privacy concerns all act as barriers to implementation and widespread voluntary use of alcohol interlocks. The lack of public knowledge regarding device capabilities may also contribute to a device's perceived intrusiveness and could hinder implementation.



New Strategic Directions

In late 2015 Austroads released its 2016-2020 Strategic Plan which repositions the peak organisation of Australian and New Zealand road transport agencies for a strong, relevant and sustainable future.

The plan outlines Austroads' purpose and role, operating principles, strategic environment, and programs and priorities.

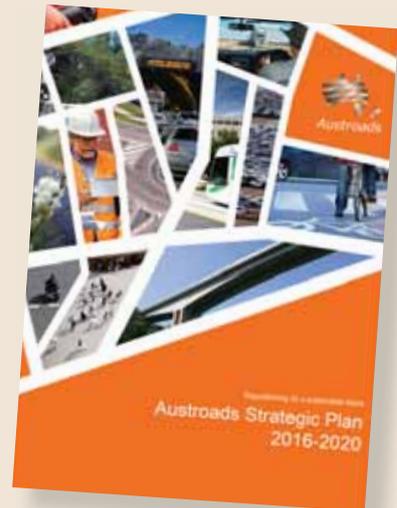
Under the new four-year plan, the new Assets, Safety and Network Programs will be led by a full-time Program Manager, a director or senior executive level staff seconded from member agencies.

Austroads Task Forces will continue to play an essential role and their membership will continue to be drawn from member agencies. Task Force members will meet two to three times a year to identify research needs and Austroads Guide updates, share project progress, discuss issues and share practices.

The number of projects Austroads manages each year will be significantly reduced. The projects undertaken will be of larger scale with more significant outcomes.

Project development and delivery will be more responsive and agile. This will mean that some projects may need to be turned around in less than 12 months and may fall outside the standard project development time-frame. Austroads will develop project management and budgetary processes that allow for this rapid identification and delivery of projects. There will be a greater emphasis on delivering projects on time and on budget.

Austroads will provide greater transparency in the development and purchasing of research contracts. New contracts, where appropriate, will be open to competitive tender. This will enable Austroads to consistently engage highly skilled teams of specialists who can provide strong value for investment.



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Resources

All Austroads research reports are available for free from www.onlinepublications.austroads.com.au after logging into the site.

The Austroads corporate website www.austroads.com.au has details about each of the Task Forces and their work programs.

Productivity growth in the headlines, but what about on the road?

by Christopher Melham
Chief Executive
Australian Trucking Association

The trucking industry is currently the subject of a plethora of recommendations and reviews, which seem to be largely focused on improving Australia’s long-term road freight productivity.

There’s good reason to pay attention to it. Road freight productivity has slowed in recent years. Between 1971 and 1991, heavy vehicle productivity tripled, with an average productivity growth of 6.24 per cent each year. Since 1991, this growth has almost halved, with annual heavy vehicle productivity growth of 3.5 per cent.

With the national freight task forecast to grow by 80 per cent between 2011 and 2031, it’s essential that we see real productivity reform in order for trucking businesses to be able to meet this growing challenge.

But despite the recommendations and reviews, progress is slow. While we appreciate the importance of long term

strategies, it’s for the long term – initial reports can take years, let alone actual implementation. Who is looking out for our short term outcomes?

I fully appreciate the complexities involved in national heavy vehicle law reform, particularly where multi-jurisdictional concerns need to be juggled. However, I cannot forgive the ongoing delays in short-term productivity initiatives to help trucking operators here and now.

We’ve been told that they are too difficult to achieve, or outside the scope of whichever review is underway. But they’re gettable, and will deliver real short term gains to both our industry and the economy.

I believe there are real reforms that can be undertaken right now to improve short-term productivity for our industry. These must include:



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And with new 45-foot containers now coming into use in Europe and North America, it's essential that longer combinations like super B-doubles are given access to port areas so they can handle these long loads.

The current formula used to assess the maximum weight allowed on bridges should also be reconsidered. This formula is outdated and grossly overestimates the infrastructure wear caused by modern heavy vehicles, thus needlessly restricting heavy vehicle access to some areas.

Resolving first and last mile access issues, sooner rather than later. I commend the NHVR's current progress in this area at the local government level. However, I contend that more is needed. In particular, having councils move away from permits to more approved routes will drastically cut red tape in this area, in addition to the productivity gains from providing the access in the first place.

Supporting the recognition of third party heavy vehicle safety accreditation programs, such as TruckSafe, that meet a national standard.

Government businesses should not hold a competitive advantage purely because of their ownership. There needs to be fair and comparable treatment of industry accreditation schemes owned by industry, such as TruckSafe, and government, such as NHVAS. This includes giving accredited operators access to the same regulatory benefits when they meet equivalent standards.

Finally, government should **review and develop national guidelines on local noise curfews** for the port, retail distribution and waste sectors.

Very often, well-meaning proposals to increase industry productivity and reduce urban congestion are stymied by government regulation that restricts industry's ability to do its work outside of peak periods.

Productivity improvements won't happen in a vacuum. But these short-term improvements will give trucking operators and governments the breathing room they need while slower, long-term plans come into fruition.

Head Office News

Welcome to Bronze Corporate members

The George Institute for Global Health, Missenden Road, Sydney

Chapter reports

Victorian Chapter

Congratulations are extended to Jessica Truong who is taking some time off from TAC to take up a position with Global NCAP in 2016. She will be based in London as the Programmes Director and Asia Pacific Coordinator. Our thanks go to Jessica for her work as the Victorian Chapter Chair and we wish her well in her new role. We welcome Melinda Spiteri as the Victorian Chapter Chair in the interim - until the AGM early in 2016 when the positions will be determined for the new terms of office.

ACT and Region Chapter

This has been another satisfying year for the ACT and Region Chapter. Our activities have been successful and we have continued to develop our relationships with major road safety organisations in the ACT and surrounding regions, particularly with the ACT Government and NSW local government shires and councils.

Since the previous report, the ACT Government has announced the first appointed members of the ACT Road Safety Fund Advisory Board. The ACT Road Safety Fund was established in July 2015 to fund projects and initiatives related to road safety research and education and road trauma prevention, in support of the Government's road safety strategy. The Road Safety Fund replaced the NRMA-ACT Road Safety Trust, in light of additional Compulsory Third Party (CTP) insurers entering the ACT CTP market.

The Road Safety Advisory Board will provide advice about the application of the ACT Road Safety Fund, including a community road safety grants program. The road safety contribution levied by the Government on ACT vehicle registration will be used for projects driven by the Fund. The contribution of \$2.50 per vehicle will generate

New Guidelines Released

ATA releases truck and dog stability guide

The Australian Trucking Association has published a revised and updated version of its truck and dog Technical Advisory Procedure, which provides best practice advice for achieving dynamic stability with these combinations.

ATA Chief Executive Christopher Melham said vehicle stability was a key safety issue for all trucking operators, but little guidance was available for optimising truck and dog combinations.

“Under the Australian Design Rules, the truck and towed dog trailer are assessed as two separate vehicles, which may then be put together into a truck and dog combination,” Mr Melham said.

“While completely legal, this means that operators may not receive guidance on how they can optimise the safety and stability of these combinations.

“This advisory procedure provides step-by-step instructions and formulas to help operators improve the overall performance, dynamic stability and safety of their truck and dog combinations.

“The formulas cover five different common truck and dog combinations between 42.5 and 50 tonne Gross Combination Mass. In general, the formulas promote longer

wheelbases for both the truck and trailer, reducing coupling offset, and lowering the combination’s centre of gravity.”

The advisory procedure was developed by the ATA’s Industry Technical Council, which includes operators and suppliers with leading expertise in truck technology. This is the latest in the ATA’s series of technical advisory procedures, which provide best practice guidance for trucking operators, maintainers and suppliers about key technical issues. The procedures are available for free from the ATA’s online resource library: <http://www.truck.net.au/resource-library>

Developing a heavy vehicle fatigue data framework: discussion paper

This report developed collaboratively by the National Transport Commission, the National Heavy Vehicle Regulator and the Alertness Cooperative Research Centre (CRC) identifies how governments can work together and with industry to develop a national heavy vehicle data framework to collect and analyse fatigue data to better inform future policy.

The report proposes framework activities which include: standardisation of crash investigation recording, improved data collection, industry surveys and new scientific research in partnership with the Alertness CRC. The discussion paper can be found at:

[http://www.ntc.gov.au/Media/Reports/\(42AFE3BC-3728-4940-BFC6-A8DAFE4C94E8\).pdf](http://www.ntc.gov.au/Media/Reports/(42AFE3BC-3728-4940-BFC6-A8DAFE4C94E8).pdf)

Road Safety Management Leadership Program



MONASH University
Accident Research Centre

The Monash University Accident Research Centre is holding its fifth innovative Road Safety Management Leadership Program at the Monash University Law Chambers, 555 Lonsdale St, Melbourne on 2-6 May, 2016. The program is designed to develop and nurture the next generation of road safety leaders tasked with achieving improvements in road safety performance over the coming decades.

It addresses road safety leadership and management challenges faced internationally, including Australasia, in responding to the circumstances which apply in high, low and middle income countries. Drawing upon presenters with extensive international experience in these environments, it will comprise an intensive process of formal presentations, interactive case studies, group work and panel discussions conducted over five days at the Monash University Law Chambers in the Melbourne CBD.

A strong feature of the program is its integration of road safety management, science and leadership topics. It has been designed to ensure an interactive and dynamic engagement between the teaching team and program participants that works through best practice science and its potential application for improved road safety results.

Please visit the MUARC Road Safety Management Leadership Program website here: <http://www.monash.edu/miri/research/research-areas/transport-safety/leadership>.

All enquiries can be directed to:

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Peer-reviewed papers

Prevalence of affective states in Australian truck and train drivers

by Taryn Chalmers¹ and Associate Professor Sara Lal¹

¹ Neuroscience Research Unit, School of Life Sciences, University of Technology Sydney

This paper is an extended version of an earlier conference poster that was presented at the ARSC 2015. It has undergone further extensive peer review; revised with additional material added.

Abstract

Within this exploratory preliminary study, data is presented regarding the prevalence of specific mood states within a sample of Australian truck and train drivers. A total of 49 heavy vehicle truck drivers and 58 train drivers were recruited from the local community. Subjects completed a mood state questionnaire. Numerous mood states (tension-anxiety, depression-dejection, anger-aggression, fatigue-inertia, confusion-bewilderment and total mood disturbance score) were found to be significantly higher ($p < 0.05$) in the truck-driving sample than the train driving sample, and higher than the advised normative values.

Keywords

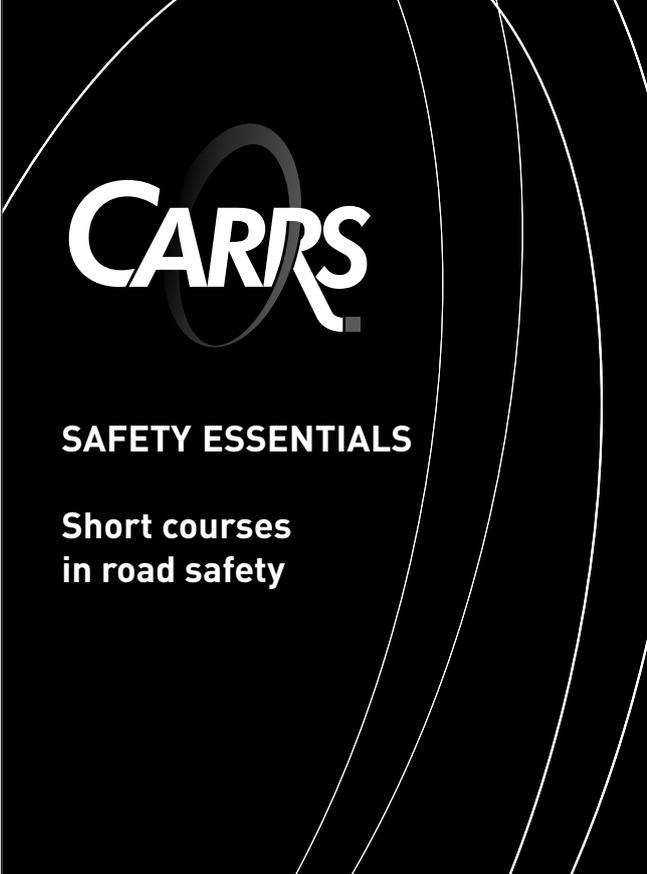
Depression, Truck driving, Train driving, Mental illness, Mood states

Introduction

The professional driving industry plays a vital role in the movement of people and goods and in the prosperity of Australia. A combination of extensive distances between industries and a low population density has resulted in a large reliance upon road and rail freight. Occupational conditions within Australia's heavy vehicle and train driving industries are often comparable, frequently requiring both physiological and psychological demands. Long hours spent sitting, workplace isolation, sporadic rest and work cycles, monotonous driving conditions, the pressure to meet delivery schedules and the need for continuous alertness are some of the common inherent occupational demands of these two industries, some of which may contribute to impaired driver health. Mood or affective disorders such as depression have been frequently reported in overseas epidemiological studies of mental health within the professional driving industries (da Silva, 2009), however the paucity of literature regarding the incidence of depressive symptomatology within an

Australian sample of professional drivers is concerning. Depression has been increasingly correlated to a reduction in driver performance, with recent studies having found that severe and extremely severe depression in truck drivers resulted in a significantly increased odds ratio (4.4 and 5.0 respectively) for an accident or near miss (Hilton, 2009). Studies have also found links between self-reported negative mood states and electroencephalography fatigue indicators (Lal, 2002). It is important to ascertain accurate statistics regarding the incidence of depression and other negative mood states within these professional drivers in order to provide the foundation for the improved management of these illnesses within these occupational fields.

There is an increased incidence of the affective disorder, depression within the professional driving industry. A study conducted by Hilton and associates (Hilton, 2009) found that 13.3% of Australian heavy vehicle truck drivers demonstrated at least a mild form of depression (as measured by the Depression, Anxiety and Stress Scale (Lovibond, 2002) in contrast to the national rate of 11.6% (World Health Organisation, 2009). In comparison, a study by da Silva-Junior and team (da Silva, 2009) found that 13.6% of the truck drivers ($n=300$) suffered from depression (as diagnosed through the section Major Depressive Episode in the Mini International Neuropsychiatric Interview (Sheehan, 1998). Supporting this, Wong and team found that 14.5% of truck drivers felt more depressed once commencing work within the truck driving industry (Wong, 2007). Recently, work stress has been heavily implicated as an independent predictor of depression (Wang, 2005). The common workplace conditions mentioned previously imply that truck drivers can be viewed as a depression vulnerable population. Furthermore, the association of long working hours with increased incidence of depression has been supported by a study by Virtanen and colleagues which found that working more than 11 hours per day demonstrated an increased odds ratio for developing depressive symptomatology (Virtanen, 2012).



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Despite the previously mentioned, well-documented high rates of depression amongst professional truck drivers, at present, there have been few epidemiological studies regarding the presence and effects of depression within truck and train drivers in Australia. Although a National Standard for Health Assessment of Rail Workers (National Transport Commission, 2012) has been implemented within the rail industry, which assesses psychological disorders amongst a range of health conditions, the true prevalence of depression within this industry remains somewhat unclear. With train drivers in Australia frequently subjected to comparable working conditions to that of truck drivers (such as long working hours, monotonous driving conditions, etc.), it would stand to reason that there may be an elevated risk of depression in both professions. As such, elucidating the rates and effect of depression in drivers within these transport industries is an important safety issue in Australia.

In Australia, rail suicide accounts for 6-8% of the nation's death by suicide, totalling approximately 150 rail-related deaths per annum (Lifeline, 2012). Witnessing rail-suicide is a serious issue that has been known to result in extreme psychological distress that can progress into a number of psychological conditions such as depression (Cothureau, 2004). A study conducted by Cothureau and associates in France (Cothureau, 2004) assessed 388 train drivers, either those having been exposed (n=202) or not-exposed

(n=186) to a rail suicide whilst operating a train. The study found that those individuals in the exposed cohort had significantly higher rates of post-traumatic stress symptoms ($p<0.0001$), somatic symptoms ($p<0.0001$), anxiety and insomnia ($p<0.001$). A total of 1.5% of the assessed drivers exhibited severe depression; with other affective disorders also being observed, such as generalised anxiety disorder (4.0%), dysthymia (1.0%), panic disorder (0.5%) and manic episodes (0.5%). Collectively, these findings provide a unique insight into the acute occupational stressors encountered by train drivers, and the psychological effects of these stressors. Another study, assessing the psychological health of train drivers, conducted by Loukzadeh and associates (Loukzadeh, 2013), found that 15% of the 152 train drivers assessed exhibited scores of greater than 19 on the Kessler Psychological Distress Scale (Anderson, 2013), indicating that they were likely to have a mild, moderate or severe mental disorder. Although this study did not assess depression specifically, it does provide some evidence for the impaired psychological health of individuals within this field.

When we consider the acute and chronic effects of depression on the quality of life of an individual, it is clear that elucidating the true prevalence of affective disorder within the rail and truck industries is vital to preserving the health of drivers in these industries. The effect of managing depression in these drivers would not only benefit

the drivers but will also be beneficial to employers who employ these drivers. A recent PricewaterhouseCoopers report estimated that Australian businesses will lose \$10.9 billion annually for neglecting to address mental health in the workplace (PricewaterhouseCoopers, 2014). However, businesses that take action will, on average, experience a return of \$2.30 for every \$1 invested in initiatives that promote improved mental health in the workplace. The transport industry boasts an even higher return, with an average of \$2.80 returned for every \$1 invested (PricewaterhouseCoopers, 2014).

However, of concern is the scarcity of studies regarding depression in the trucking and train driving industries in Australia. Aside from the aforementioned study conducted by Hilton and associates (Hilton, 2009), the rate of depression in Australian heavy vehicle drivers has been somewhat overlooked. Of further concern are the statistics regarding the adverse effects of depression on driver performance. Furthermore, the likelihood of seeking appropriate medical advice for the management of depression in Australia is disturbing; with a recent Australian Bureau of Statistics survey finding that only 35% of Australians who had experienced a mental illness in the prior 12-month period had sought to access appropriate medical assistance. Despite a higher incidence of depression amongst females when paralleled with males in Australia (14.5% and 8.8% respectively), (Australian Bureau of Statistics, 2007), a well-established social perception, which discourages males from seeking medical assistance, has resulted in lower diagnostic rates of affective disorders among males (Klint, 2004). Due to the severe gender bias of the truck and train driving industries, an underlying incidence of undiagnosed affective disorders may be present, supporting the investigation of this mental disorder within drivers in this occupation.

Therefore, the aim of the present exploratory, preliminary study was to assess the presence of mood (affective) states within the Australian trucking and train driving community. By understanding and evaluating the presence and effect of depression in the Australian truck and train driver community, we would be able to provide the quantitative information required for management practices geared towards reducing the effects of these disorders on driving ability, and thus, contribute towards improving road safety in Australia, as well as extrapolate the benefit internationally.

Methods

Participants

A total of 49 truck drivers (mean age 36.50 ± 9.67 , $n=45$ males, $n=4$ females) and 58 train drivers (mean age 39.16 ± 10.51 , $n=53$ males, $n=5$ females) were recruited. Participants were recruited through local advertisement via a poster, recruitment through contacts established independently to this research, online forums and with the aid and endorsement of Australia Post Transport Division, Sydney Trains and the Australian Trucking Association. Participants

were required to be employed as a truck driver, regularly driving a truck with a gross vehicle mass of over 4.5 tonne, or a currently employed train driver.

Procedure

The study was comprehensively detailed to the subject upon arrival, with the opportunity for questions being posed. Upon receipt of written consent, the study was commenced. The following questionnaires were administered in the study.

SmartData questionnaire

The SmartData questionnaire (modified from a questionnaire developed in-house (Kavanagh, 2007) helps obtain demographical information regarding licensing, trucking history, employment status, nutrition, accident history and working conditions. This questionnaire was utilised as a basis for possible stratification of data, and to ascertain common conditions of truck driving in Australia.

Profile of Mood States questionnaire

The Profile of Mood States questionnaire (POMS) (McNair, 1971) is composed of 65 items describing six mood subscales: tension-anxiety, depression-dejection, anger-hostility, vigor-activity, fatigue-inertia, and confusion-bewilderment. An overall measure of total mood disturbance is calculated for all six subscales by combining the scores obtained on the tension-anxiety, depression-dejection, anger-hostility, fatigue-inertia and confusion-bewilderment scales minus the score on the vigor-activity scale. The depression-dejection subscale has been shown to be strongly predictive of the Beck Depression Inventory-II (BDI-II) (Beck, 1996), which is often used in clinical practice to diagnose depression. The depression-dejection subscale of the POMS is consequently considered a useful short alternative to the BDI-II, since it also investigates other components of mood such as anxiety and aggression (Griffith, 2005). The POMS questionnaire is a subjective measurement of well-being, and is an assessment of an individual's mood state during the previous week, including the day of participation. This questionnaire is a reliable, low cost, ergonomic psychometric tool that has been highly validated by numerous previous studies (Norcross, 1984). The participant was asked to tick the box that corresponded to the intensity of each feeling stated, from "Not at all" to "Extremely" through a five-point progression from 0 to 4. For example, next to the feeling "Angry", a participant may either mark "Not at all", "A little", "Moderately", "Quite a bit" or "Extremely". After the completion of this questionnaire, the scores for each subscale, and a total mood disturbance score, were calculated. Normative values for the POMS questionnaire were obtained from a study conducted by Nyenhuis and associates which prepared normative adult values using a sample of 400 individuals (Nyenhuus, 1999), who were age-, gender-, and race-stratified according to 1990 census data.

Results

Using independent sample t-tests, it was ascertained that the train and truck driving samples were age ($p = 0.12$) and body mass index (BMI) matched ($p = 0.28$) (Table 1).

Table 1. Descriptive statistics of current sample

Sample group	Mean BMI	Mean age (years)
Train drivers (n= 58)	29.1 ± 4.86	39.16 ± 10.51
Truck drivers	28.5 ± 3.40	36.50 ± 9.67

BMI = Body mass index (weight (kilograms)/height (m²))

Truck drivers presented significantly higher levels of negative mood states than train drivers (Table 2). Tension-anxiety ($p = <0.0001$), anger-aggression ($p = 0.004$), fatigue-inertia ($p = 0.023$), depression-dejection ($p = <0.0001$), confusion-bewilderment ($p = <0.0001$) and total mood disturbance ($p = <0.0001$) were all significantly higher in the truck driving sample than in the train driving sample. It should also be noted that through single sample t-tests, it was ascertained that scores were higher for all negative mood states and lower for vigor activity in the truck driving sample than the advised normative values (Nyenhuis, 1999). The train driving sample presented scores comparative to normative values for all mood states, other than confusion-bewilderment and vigor-activity, which were significantly lower than advised normative values.

Discussion

The present preliminary study identified a concerning trend of high levels of negative mood states within the Australian truck driving sample. Levels of all negative mood states in the truck drivers were both higher than the advised normative values, and the train driving sample scores. High levels of negative mood states have been consistently linked with a decrease in driver performance (Hilton, 2009; Lal, 2002), which when considered alongside the high levels of negative mood states reported within the truck driving sample, raises concerns about driving safety and warrants further investigation.

Tension-anxiety, anger-aggression, fatigue-inertia, depression-dejection, confusion-bewilderment and total mood disturbance were all found to be significantly higher in the truck drivers compared to the train drivers. Impaired mental health in the workplace elicits negative impacts on both employees and employers and can compromise work performance and safety. From increased absenteeism (PricewaterhouseCoopers, 2014), to high numbers of approved compensation claims for mental or stress related illnesses (Safe Work Australia), neglecting to appropriately address psychological based illness can impact negatively on all parties involved. As previously mentioned, Australian businesses will lose \$10.9 billion annually for neglecting to address mental health issues in the workplace (PricewaterhouseCoopers, 2014). However, the return for industries that invest in mental health schemes is both economically beneficial, and valuable to ensure employee health and transport safety.

Table 2. The average scores attained for the six mood subscales, the total mood disturbance score in truck (n=49) and train drivers (n=58) and normative values ±

Sub-scale	Truck driver mean score	Truck driver mean score	Normative values (Adult population)
Tension-anxiety	12.8 ± 5.4*#	5.9 ± 5.6	7.1 ± 5.8
Anger-aggression	10.2 ± 6.3*#	5.6 ± 7.1	7.1 ± 7.3
Fatigue-inertia	13.0 ± 6.4*#	8.3 ± 6.2	7.3 ± 5.9
Depression-dejection	16.3 ± 10.2*#	5.6 ± 7.4	7.5 ± 9.2
Confusion-bewilderment	10.0 ± 4.9*#	3.8 ± 2.1#	5.6 ± 4.1
Vigor-activity	11.1 ± 5.3*#	17.7 ± 4.7#	19.8 ± 6.8
TOTAL MOOD DISTURBANCE	51.3 ± 34.2*#	13 ± 22.0	14.8 ± 32.9

Key:

* = significantly different to train driving sample ($p < 0.05$)

= significantly different to advised normative values ($p < 0.05$)

Conclusion

Collectively, the findings from the present preliminary study provide a novel perspective on the mental health of Australian truck and train drivers. The present study addressed the gaps in research by assessing a number of mood states (tension-anxiety, depression-dejection, anger-aggression, fatigue-inertia, confusion-bewilderment and total mood disturbance score) within these understudied occupational industries. The preliminary study found that multiple mood states were significantly higher in the truck-driving sample than both the train driving sample, and the advised normative scores. This provides evidence for future research into the incidence of these negative mood states within these understudied industries.

There are a number of limitations within the current preliminary study. Sample size, whilst large enough to provide adequate sample power, should be increased for each sample group (truck and train drivers) in order to provide a representative distribution of the population, and ensure that results are able to be generalised across each of the occupations. Furthermore, drivers were recruited from the Sydney area, and thus, may not be representative of the entire Australian driver population for each sample. Future studies may benefit from recruitment of drivers from a number of suburbs and states across Australia.

Drawing from preceding literature, reducing the incidence of these negative mood states could work to improve mental health within the truck driving industry, and in turn, increase driver performance, thereby improving road safety in Australia. It is vital, however, that future studies use larger sample populations and recruit professional truck and train drivers from a number of different suburbs and states across Australia to ensure an accurate representation of each of the occupational populations.

These preliminary findings provide evidence for further investigation into the incidence of negative mood states within these two occupational fields. Considering that heavy vehicle accidents reportedly cost Australia approximately \$2 billion each year (Bureau of Infrastructure Transport and Regional Economics, 2009), quantitating the presence of mental disorders, and improving the mental health profile of these individuals may, in turn, reduce the effects of disorders such as depression on driving ability. Road safety in Australia is a vital aspect of the transport industry that requires a holistic, well-researched management approach. By incorporating mental health and psychological management schemes, the safety advantages in terms of improved driver ability and performance, and reduction in both absenteeism and psychological disorders, would be highly beneficial.

Acknowledgements

We acknowledge the driver participants for undertaking the study in the Neuroscience Research Unit at UTS. Thanks also go to Australia Post Transport Division, Sydney Trains and the Australian Trucking Association for helping with recruitment of the study sample. Finally, we acknowledge the use of a modified version of the Smart Data Questionnaire (author Diarmuid Kavanagh).

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Safety culture and speeding in the Australian heavy vehicle industry

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This paper is an extended version of an earlier conference paper that was presented at the ARSC 2015. It has undergone further extensive peer review; revised with additional material added.

Abstract

Inappropriate speed and speeding are among the highest causes of crashes in the heavy vehicle industry. Truck drivers are subjected to a broad range of influences on their behaviour including industrial pressures, company monitoring and police enforcement. Further, drivers have a high level of autonomy over their own behaviour. As such, it is important to understand how these external influences interact with commonly shared beliefs, attitudes and values of heavy vehicle drivers to influence behaviour. The present study uses a re-conceptualisation of safety culture to explore the behaviours of driving at an inappropriate speed and speeding in the heavy vehicle industry. A series of case studies, consisting of interviews and ride-along observations, were conducted with three transport organisations to explore the effect of culture on

safety in the heavy vehicle industry. Results relevant to inappropriate speed are reported and discussed. It was found that organisational management through monitoring, enforcement and payment, police enforcement, customer standards and vehicle design factors could all reduce the likelihood of driving at inappropriate speeds under certain circumstances. However, due to weaknesses in the ability to accurately monitor appropriate speed, this behaviour was primarily influenced by cultural beliefs, attitudes and values. Truck drivers had a tendency to view speeding as relatively safe, had a desire to speed to save time and increase personal income, and thus often attempted to speed without detection. When drivers saw speeding as dangerous, however, they were more likely to drive safely. Implications for intervention are discussed.

Introduction

Inappropriate speed and speeding are among the highest causes of crashes in the heavy vehicle industry. Driving above the posted speed limit and/or too fast for the conditions is a well-known risk factor for traffic incidents. Driscoll (2013) reported on 461 major heavy vehicle crashes in 2011, stating that inappropriate speed was responsible for 25.4% of these crashes. This figure was reportedly lower than in previous years. Chen and Chen (2011) examined 10 years of crash data from Illinois, USA, finding that speed influences the severity of outcomes in single-vehicle truck crashes, yet not multiple vehicle crashes (lack of an increase in severity in multi-vehicle crashes may be associated with the likely severity of a light vehicle crashing with a heavy vehicle, regardless of speed, due to the size and mass of the truck). Finally, Brodie, Lyndal and Elias (2009) analysed coroners' reports, finding that excessive and/or inappropriate speed was involved in 43.1% of fatalities in which speed was documented.

A number of researchers have indicated that safety culture could provide a useful avenue for improving safety in the heavy vehicle industry (Gander et al., 2011; McCorry & Murray, 1993; Short, Boyle, Shackelford, Inderbitzen, & Bergoffen, 2007). Safety culture has seen significant attention within the literature in recent years, and there is significant debate about the nature of safety culture and how it can be defined (see reviews by Choudhry, Fang, & Mohamed, 2007; Edwards, Davey, & Armstrong, 2013; Guldenmund, 2000). There are two major approaches to safety culture in the literature. One views safety culture primarily in terms of organisational structures and systems, and has been called a normative or functionalist approach (Edwards et al., 2013; Nævestad, 2009). The other, views safety culture primarily in terms of shared beliefs, attitudes and values, and is referred to as an anthropological or interpretive approach (Edwards et al., 2013; Nævestad, 2009).

In a previously published review, the authors examined journal articles about heavy vehicle driver health and safety identifying a broad range of influences on health and safety in heavy vehicle industries (Edwards, Davey, & Armstrong, 2014). These included government regulations and enforcement; organisational factors; customer pressures and requirements; and road/environmental factors. In addition to these external factors, it should be noted that heavy vehicle drivers have a high level of autonomy over their own behaviour (Arboleda, Morrow, Crum, & Shelley Ii, 2003). Further, Sully (2001) suggested that due to the amount of time heavy vehicle drivers spend away from their depot, they are more likely to associate themselves with an industry wide road culture than to a specific transport company. Thus, to understand speeding in the heavy vehicle industry, there is a need to explore both external and internal influences on speeding, and to look beyond the traditional boundaries of the organisation. This presents a barrier to the application of the two traditional approaches to safety culture, which typically focus on one of these aspects in isolation and within the confines

of a single organisation. The authors previously presented an alternative approach to safety culture in which safety culture is viewed in terms of the combined impact of both external contextual elements and shared beliefs attitudes and values (Edwards et al., 2013). This framework held that safety related behaviours were influenced by the interactions between cultural and contextual factors. To date there is no strong evidence to suggest that culture can be deliberately changed (Edwards et al., 2013; Nævestad, 2009), however, by understanding the existing culture and how it interacts with contextual factors, it may be possible to change these contextual factors to work with the culture of a workforce to improve safety (Edwards et al., 2013, 2015). The present study uses this framework of safety culture to explore the effect of culture on speeding in the heavy vehicle industry, in order to identify potential approaches to reduce speeding.

Method

A series of three qualitative case studies with transport organisations were conducted to investigate safety culture within the Australian heavy vehicle industry. These case studies formed a collective case study (Stake, 2005), in which the three organisations chosen for the research were selected to provide insight into the broader industry. The case studies were conducted using a combination of ethnographic methods (interviews and participant observations) and grounded theory analysis techniques (specifically those of Corbin & Strauss, 1990).

Participating organisations

The three participating organisations (identified here as Company A, B and C), were selected on the basis of knowledge from a series of preliminary interviews. These interviews indicated that both safety and culture in the industry differed depending on location; type of vehicles used and goods transported; distance of haul; and size of employing company. After examining the results of these preliminary interviews, the researchers sought companies which would provide insight into these different sections of the industry. Through examining websites of transport companies, some of which had participated in the preliminary interviews, a shortlist of potential case study organisations was developed. Due to the duration of time required to collect and analyse data, recruitment emails were sent to managers of one company at a time (to avoid long delays between agreement to participate and participation). One company was unable to participate due to a depot closure, and another due to an ongoing investigation related to a fatal crash, however, the remaining approached organisations participated in the study. After initial consent was provided, a brief meeting was held with the company managers to ensure that the organisation was suitable for the study.

A total of three companies participated in case studies. The key differentiating characteristics, based on the preliminary interviews, for each company can be seen in Table 1.

Table 1. Case study organisation characteristics

	Company A	Company B	Company C
Company Size	Medium (~50 trucks)	Medium (~50 trucks)	Small (<10 trucks)
Location Type	Capital city	Capital city	Regional centre
Major Freight Task	General goods	Specialised freight	Livestock
Typical Distance Carried	Medium-long (intra- and inter-state)	Local (plus some medium-long)	Short-medium (within region)
Main truck types	Semi's and B-Doubles	Rigid, crane mounted, heavy haulage, long loads, semi's and B-doubles	Semi's, B-doubles and road trains

Company A was a medium-sized family-owned and operated transport company. The organisation employed approximately 100 staff and owned over 50 prime movers. Semi-structured interviews and observations were conducted with 10 staff members. Four managerial, administrative and operational staff (two managers, one health and safety officer and one operations manager), along with six heavy vehicle drivers, took part in interviews. Six observations were also conducted with heavy vehicle drivers.

Company B was a medium sized transport company, employing approximately 100 staff with over 50 trucks. Due to the diversity within Company B, the organisation had a number of managers overseeing branches within the company. Ten interviews were conducted within Company B. Participants consisted of the compliance officer, and part owner, of the company; two regional managers who each oversaw approximately half of the fleet; five branch or depot managers; two driver trainers; and an operational manager. Eight observations were conducted, typically covering a driver's shift.

Company C was a small-sized transport company based in a regional centre. Family owned and operated, the organisation consisted of six prime movers and various trailers, and employed between six and 10 people at any point in time. Five interviews were conducted with the owner/manager, compliance officer, two drivers, and the owner/driver/head-mechanic. Three observations were conducted.

Data collection and analysis

The interviews lasted between 30 minutes and two hours, and covered a variety of topics. The first questions were typically aimed at eliciting information regarding the history of the individual and identifying major safety concerns. Later questions sought to identify contextual, cultural and behavioural factors which influence these safety concerns. Participants were asked about specific behaviours and outcomes which were not spontaneously discussed. Prompts were seldom required as participants appeared eager to share their perspectives on safety.

Typically conducted after the interviews, observations of drivers occurred during drivers' usual shifts. Most observations lasted the duration of the shift; although some lasted for a portion of the shift (range of durations was 4-15 hours, with the exception of two which occurred to take the researcher to another depot). During observations the researcher conducted informal interviews similar in nature to the staff member interviews. Additionally, questions were asked which specifically related to tasks witnessed.

The collected data was analysed with the NVivo software package, using the grounded theory analytical techniques outlined by Corbin and Strauss (1990). Traditionally, three levels of coding are used, including open coding (identifying key broad categories), axial coding (identifying sub-categories and the relationships between them) and selective coding (associating the identified categories and sub-categories around a key theme). For the purpose of this study, it was necessary to ensure that the research was approached in an open and inductive manner; however, it was also important to ensure that the findings accurately reflected the theoretical constructs of safety culture. As such, open coding in this study consisted of identifying where participant responses referred to cultural (shared beliefs, attitudes and values), contextual or behavioural factors. Axial coding for this study involved identifying key categories and sub-categories within these broader factors (e.g. government enforcement and speed cameras, within the broader 'contextual factors'). Finally, selective coding involved identifying how these categories and sub-categories were associated with speeding behaviour, through links made by participants, and responses which were coded for both speeding behaviour and specific cultural and contextual factors.

Results and discussion

Throughout the case studies a significant degree of congruence was found across members of the three companies. As the case study companies were selected to provide a broad overview of perceptions within the industry from differing subsections, this congruence allowed the case studies to be interpreted collectively as originally intended. This gives support to the notion of an industry wide culture. For the purpose of this paper, differences

between companies will be noted where relevant, however, the majority of discussion will incorporate responses from members of each company to shift focus from specific companies toward the broader industry. It should be noted that during observations and interviews with drivers only hand written notes were taken, reducing the possible length of quotes. Conversely, during interviews that occurred with staff members, audio recordings were made. As such, the majority of large quotes are from managers. Nonetheless, the quality of hand-written notes permitted analysis to be conducted both on verbatim quotes from audio recordings and written notes. As such, while the majority of reported quotes are from managers, the analysis allowed equal voice to drivers and staff members.

Participants generally acknowledged speeding to encompass both driving at an unsafe speed for the conditions and exceeding the posted speed limit. Heavy vehicles are legally required to be speed limited to prevent speeds exceeding 100km/h. As such, this limiting technology only reduces speeding on highways with a posted speed limit of 100km/h or greater. Thus, it was concerning that many participants tended to define speeding as exceeding 100km/h. When asked about speeding one Company B driver stated, due to the speed limiter, “I can’t speed”. Similarly, the driver/manager of Company C (He both managed the company and drove a truck) said that their drivers “can’t speed because they’re limited”. Given that heavy vehicles can easily exceed lower posted speed limits this perception is clearly flawed, but highlights that some participants thought speeding was not a possibility.

There were a broad range of factors suggested by participants to be associated with speeding behaviour and the likelihood of outcomes. These included both contextual and cultural factors. For the purpose of the present discussion contextual factors will be discussed in brief, leaving room for a greater discussion of cultural beliefs, attitudes and values.

Contextual factors influencing speeding

Many of the contextual factors identified by participants as being related to speeding and speed-related crashes were commonly known risk factors. These included factors such as inclement weather reducing the safe speed of travel, and other vehicles and road works causing delays which lead to increased work pressures. Of particular importance however were the roles of law enforcement, organisations and customers.

Law enforcement and speeding

Traffic law enforcement is a cornerstone of road safety strategies worldwide. With regards to heavy vehicles and speeding, there were three main methods of monitoring and enforcement. These were (1) speed limiters (on all heavy vehicles except those too old for the technology), (2) fixed camera enforcement (standard and point-to-point), and (3) mobile enforcement. Whilst each of these has some merit, there were weaknesses identified by participants which reduce their deterrent effect.

Speed limiters were seen as easy to tamper with for those who wish to do so. In addition to the fact that speed limiters only set a maximum speed, which does not adapt to varying speed zones, it was noted that the mechanism by which speed limiters operate does not prevent speeding downhills.

The road speed is gutted at 100km/h. They will go faster than that off a hill because they’re not gear-bound at 100km/h but I think they’ll top out at just over 120 or something like that, 130. (Company A Manager One)

Standard speed cameras were generally seen as ineffective because truck drivers become familiar with the roads they travel and know the exact locations of each camera. Thus, drivers only need to watch their speed in these locations. Further, point-to-point speed cameras were seen as easy to overcome, as truck drivers are aware of the legal time-limits and many will time their trip and wait before passing the next camera. Additionally, delays afford additional time for drivers, allowing them to speed through lower speed limit sections without triggering fines.

SAFE-T Cams don’t stop you from speeding. There are hills between the cams so you lose speed up the hills and can go like hell down them... Going through towns slows you down so you go like stink on the highway and at daytime you hit traffic lights which can add five minutes to your time. (Company A Driver Six)

Finally, while mobile enforcement has benefits, the use of UHF radios allows truck drivers to be aware of police locations at all times on the road. Overall, these issues mean that there is an absence of certainty of punishment for speeding, and thus limited deterrence. As such, it is seen as unlucky to be caught for speeding.

I have had two speeding tickets from running off hills in the past seven months... just my bad luck that when I did it there was a cop down the bottom, plus I was on the wrong radio station so I didn’t hear about them. (Company A Driver Six)

Transport organisations and speeding

The organisation’s primary roles related to speeding come from the method in which they pay drivers, and the approaches used to monitor and enforce speed-limit compliance. Starting with the payment of drivers, hourly rates were associated with safer behaviour, as driving slower results in greater income. Conversely, as stated by one Company B driver, payment by the kilometre or load is a “good incentive to drive fast”, as travelling the same distance in less time is a more efficient way to earn money. Among the three participating companies, Company A paid a km rate for all long distance drivers, but an hourly rate for local drivers, Company B paid all their drivers an hourly rate, and finally Company C drivers are paid a salary (which was comparable to a load rate due to the inability to earn overtime if the load takes longer than expected).

Basically the drivers over at (previous employer location), they're getting paid a kilometre rate. So it's in their own interest to go like gun it all the time and they do gun it all the time... Over here they get paid on an hourly rate so they're not actually achieving anything by speeding and obviously our trucks are regulated to down to 95km and theirs are still 105, 110km. (Company B Branch Manager Two)

Each company relied on two primary means to monitor speed compliance – satellite tracking and speeding infringement notices from government departments. The satellite tracking methods of each company were capable of reporting current speeds and sending alerts to managers when vehicles exceed a chosen speed limit. Though they can be used to alert managers to different speeds in different locations, thus monitoring all speeding above the posted speed limit, they were typically only used to detect speeds in excess of the speed limiter. Company C managers did indicate that they will on occasions actively watch the tracking monitor to (from memory) determine whether the vehicle was speeding on a given road, however, this only occurred sporadically. Company B did implement specific speed zones in two locations, due to either past speeding fines or complaints by local residents regarding their trucks. As such, while there are cases of satellite tracking being used more thoroughly, satellite tracking was predominantly only used to detect speeding down hills, or speed limiters that have been subjected to tampering.

Tampering with speed limiters is easy, you just put a wire or a box over it but you can't do it without being caught. Satellite tracking shows vehicle over limited speed for an extended period of time and you know they have tampered. People are sacked immediately for it, has happened a few times. (Company A Driver Three)

Enforcement of speeding in each company was largely through non-conformance notices. For first offences and minor breaches, non-conformance notices were typically used to inform the driver that they were detected and to remind them to comply with the upper speed limit. Within Company A, one driver suggested that individual offences go unpunished, and that drivers will be reminded to slow down, yet that repeated offences are followed by non-conformance notifications, and/or one week without work and payment. However, one Company A driver stated that he had driven at “120m/h downhill but it was never followed up”.

...we normally ring up the driver and say: Oh what's the problem how come you put your foot down or what happened there? And we try and monitor that as well... Of course then we sort of have to say: Right, you know you're going to get chastised for it. You know you're not in deep shit just keep it down, keep your speed back like don't run it off the hills. (Company A Operations staff member)

Finally, infringement notices provided to companies by police grant an additional monitoring method to

organisations. In the few cases where drivers trigger a point to point or fixed camera the infringement is sent to the company, who may then reprimand the driver as desired.

Customers and speeding

Whilst customer pressures may encourage speeding, it was generally stated that customers seek to ensure driver speed compliance due to their chain of responsibility requirements. This primarily occurred through auditing company records of traffic infringements and satellite tracking, and how the company manages these. However, it should be again stated that there are weaknesses in these methods of detecting speeding.

We're closely monitored ... there's a lot of trucks here that are painted (colour with customer name) on the side. We do a lot of work for them. We're very closely monitored and essentially they even do their own audit on us every six or 12 months... To make sure we're not breaking the law. (Company A Manager One)

Contextual factors: summary

From the above contextual factors it can be seen that there is a relative lack of successful monitoring and enforcement of speeding in the heavy vehicle industry. Police enforcement was only seen as effective in the immediate presence of fixed cameras or mobile enforcement (as drivers know their location), and had limited lasting influence on behaviour. Similarly, the three organisations only successfully monitor tampering with speed limiters or running off hills. Finally, while customers may require evidence of the management of speed, due to limitations in organisational monitoring, this is not sufficiently beneficial. On the other hand, payment methods used by the company can provide incentive to either speed or drive slower. Overall this means there is an absence of sufficient external motivation to adhere to speed limits, and in some cases there is incentive to speed.

The influence of culture on speeding

A number of common beliefs, attitudes or values were identified throughout the case studies as having relevance to speeding. These broadly included seeing speeding as unintentional, viewing speed limiters as unfair, the value placed on time, and a collection of traits related to learning styles and the results these have on behaviour.

Speeding as unintentional

Generally speaking, there was a tendency to excuse speeding behaviour as merely unintentional. As stated by one manager from Company A, “everyone does it, it's not a purposeful thing”. One health and safety officer, who previously worked in road design, even indicated that truck drivers may miss the posted speed limit and drive at the speed that ‘feels’ right for the road. This unintentional speeding was linked to the need for drivers to measure travel time between point to point cameras, even though

this was also linked with deliberate punishment-avoidance strategies. Though it is clear that such behaviour can occur unintentionally, it is concerning that one of the major risk factors for crashes could be simply dismissed as unintended, and there is a need to address this issue. To prevent unintentional speeding, the use of GPS systems which inform drivers when they exceed the speed limit could be beneficial for the industry.

Speed limiting as unfair

Throughout the case studies it was evident that drivers also placed a high value on fairness, thus disliking rules or regulations that they thought were not fairly implemented. The requirement of trucks to be speed limited was often deemed unfair. While it was not suggested that cars be speed limited to the same extent as trucks, it was argued that cars should not be designed to travel as fast as current designs permit. For this reason one Company B manager stated that truck drivers feel like ‘sitting ducks’. That is, truck drivers felt that they were being unevenly regulated when compared to other vehicle drivers. This perception of unfair treatment has the potential to develop an ‘us and them’ mentality leading to feelings of hostility and resistance to regulations. Importantly, it should be noted that this feeling that regulations are unfair does not indicate disagreement with the regulation’s principles, only its application.

From the truck driver’s perspective I guess he feels like a bit of a sitting duck. you know. It is hard to control but...governed, trucks are governed to 90, cars can do 220. Why do they need to do 200? Why on earth do we have a car that does 220km/h and gets sold to a 17-year-old on his birthday? There’s nowhere in Australia you can do 220km/h, doesn’t need to go that fast. (Company B Branch Manager Four)

Value placed on time

Truck drivers commonly placed a high value on time. This has clear implications for speeding, as driving faster reduces travel time. The effect of payment was seen to have a direct impact on driver’s perceptions of the importance of time. In fact, drivers from company A (where local drivers are paid an hourly rate) commonly indicated that “on local time doesn’t matter coz you’re paid by the hour”. However, non-financial motivations for saving time also had an influence on speeding. For example, one Company A driver stated that it is beneficial to reach a destination sooner in order to sleep before the sun rises. Point-to-point speed cameras that have short intervals (e.g. 30 minutes maximum between cameras, can reduce this effect, as speeding would result in regular stopping. Nonetheless, as drivers experience delays between many cameras, it was indicated that they speed to catch up on lost time. Further, it was highlighted that in order to make up for delays and save time, truck drivers may speed through lower speed limit zones.

So they get to an 80km/h zone or a 70 or a 60 and they just keep on going. They come into an 80km/h zone and say keep doing 100. And I’m sure you’re guilty of doing it... you know you go down the road and it drops back to 80 for a section or whatever and you just keep it at whatever was the cruise control was set at. And it’s the same as truck drivers that have been stuffed around for the last hour by someone so they just hold it flat through a village to make up that time. (Company A Manager One)

Is speeding safe or dangerous?

It was evident that every truck driver who participated in the study placed a very high priority on safety. That is to say, when drivers felt that a particular course of action could lead to a crash or injuries for themselves or others, they would avoid the action. Conversely, they would always seek to conduct a behaviour they felt would improve safety. A large number of participants indicated that they perceived speeding to be a hazardous behaviour. As stated by the driver/manager of Company C “it’s dangerous to speed, shit yeah”. Similarly one Company C driver stated that another driver involved in a crash “was lucky he wasn’t going faster”. More generally, one Company A driver said “these things (trucks) are too dangerous (to speed) as far as I’m concerned”. Conversely, a number of drivers did not hold these views. For example, one Company A driver disregarded the effects of speed by suggesting that speed was irrelevant if someone cuts in front of you. As this driver believed that most incidents were caused by other vehicles, speeding was not considered dangerous. The primary mechanism through which truck drivers determined what was safe and dangerous was their own experience and stories of other drivers. It was common throughout the observations for drivers to explain why they believed a specific action either increased or decreased safety from their own experiences as well as stories of other drivers. This may have a long historical foundation in the industry as, in past years, truck drivers were often left with the sole responsibility of safety, while managers and organisations gave little priority to safety. While this has shifted, there is still a reliance on personal experience and being told stories by other drivers.

It wouldn’t even be the last 20 years where there’s been a big focus on safety and I’m not saying it’s wrong, I totally agree with it. But before that, like when I was driving... your mate might come along to you and say oh just be careful tying that down it might slip and that sort of thing but there’s no real focus on safety. (Company B Region Manager Two)

‘Normalisation of deviance’ was a phrase first used to describe a process evident in the challenger space shuttle disaster. Vaughan (1996) argued that after successive disaster-free flights involving shuttles with the same flaws present in the Challenger shuttle, members of NASA began to believe the flaws were acceptable. This process of past experiences justifying unsafe acts was referred to as normalisation of deviance. In the case of the heavy vehicle industry, while crashes are far too common at an industry

wide level, for the individual driver or company, crashes are very rare. Thus, the reliance on stories and experience creates a vulnerability to normalisation of deviance within the industry. One Company A manager stated that their organisation had experienced very few speed-related crashes, as they were mostly related to other causes. This was immediately preceded with discussions regarding truck drivers choosing to speed through towns. The lack of experienced incidents that were attributed to speed in this case led to a false confidence in the safety of speeding.

A lot of the highway is 100 but through the towns and that it is somewhat of an issue because blokes like to make up time so of course they speed through towns. We have very, very few speed-related crashes. They're normally road condition-related or stupidity-related or fatigue-related. (Company A Manager One)

The same manager indicated that one driver from the company had previously spun a truck on a highway at high speeds in the wet, yet attributed this not to speed but to the stupidity of the driver. This view was mirrored in the perspectives given by many drivers regarding speed, and highlights how false causal attributions can shape beliefs regarding the dangers associated with speeding. It should be noted however, that the reliance on stories and personal experience indicates the use of stories could present an avenue for effective training. Incident reports were used by company B in their training for a variety of safety behaviours (no specific examples of speeding were discussed by participants), and with these behaviours, there was seen to be a high level of compliance due to a belief that these behaviours were important to safety. As such, it may be possible to use this reliance on experience and stories to promote safety.

The results of seeing speeding as safe

Regarding government legislation and rules, a number of Company B drivers suggested that speed limit compliance held significant safety benefits. One driver in particular stated that “you do the speed limits for a reason, the signs are on the road for a reason, they're there for safety”. This belief that the rules exist for safety extended to many drivers with a belief that speeding was dangerous. Unfortunately, however, many drivers did not hold positive views towards speeding regulations due to a belief that speeding is relatively safe. For these drivers, they would speed, if they could do so without being detected. That is, when a driver views speeding as relatively safe, their own speeding behaviour is predominantly modified by a desire to avoid punishment, either through avoiding detection, or where not possible, temporary compliance. Given the findings with relation to monitoring and enforcement, it can be inferred that this means that drivers have the ability to regularly speed in zones with a posted speed limit lower than the 100km/h speed limiter installed in the vehicle, or when going down hills. This again highlights the need for drivers to believe that speeding is relevant to safety.

Conclusions

The case studies reported in this paper were conducted with three transport organisations taken from distinct sections of the industry, which according to industry members should have been quite different. The high level of congruence between each company gives some support to Sully's (2001) assertion that there may be a broad industry wide culture, pervading beyond the traditional organisational boundaries used in safety culture research. Nonetheless, it should be recognised that without further research confirming these findings apply more broadly throughout the industry, the results of this paper should be interpreted with caution and not generalised across an entire industry. While the findings do indicate potential for generalisation, the data was drawn solely from qualitative sources, preventing estimation of average population views, and from only three companies out of a much larger industry. Additionally, each of the companies had trucksafe accreditation, which is a voluntary accreditation scheme. This may indicate that the participating companies are a biased sample of safety-conscious organisations.

A broad range of cultural and contextual factors were identified which were relevant to speeding. Consistent with past research, there were influences from government departments, organisations and customers which had the ability to influence aspects of speeding (Edwards et al., 2014). Additionally there were a number of cultural beliefs, attitudes and values which were identified in the responses of participants. Whilst these included specific attitudes towards speed limiters and a view that speeding was at times unintentional, they also included the value placed on time and a series of beliefs and attitudes related to the value drivers place on safety and the tendency to learn primarily through experience and stories. While these beliefs, attitudes and values can be seen as being at times contradictory, collectively they reveal a consistent story. It was indicated that speeding can occur unintentionally; however, this explanation appeared to be used at times to justify behaviour that was actually intentional. When speeding was intentional, it was clear that the desire to save time and make money contributed to the occurrence of speeding, conversely, for drivers who did not intentionally speed, the value placed on safety was an important motivation. In both of these later cases, it was evident that there were interactions between cultural and contextual factors which led to specific behavioural patterns, supporting the use of the current framework (Edwards et al., 2013).

It was evident that drivers placed a high value on time, and that this could lead to choosing to speed to save time, or make up for delays. Some of the reasons for this highlighted by participants could be seen as common for many light vehicle drivers (such as a desire to get home quickly), while others were specific to heavy vehicle driving (such as wanting to get to a safe rest location in time to sleep before the sun rises, making sleep difficult). That unsafe behaviour can be associated with an attempt to make up lost time is not new, and was also notably

demonstrated by Snyder (2012) in an ethnographic study of a driver persisting through fatigue in order to make up for loading delays. Importantly, the current study demonstrated the relationship between payment models and speeding to make up time. Participants clearly stated that payment by the km or load (which is interchangeable, as a given load has a predetermined location and thus distance to travel) incentivised speeding to make the same amount of money in less time. Conversely, payment by the hour was seen to reduce the value placed on time, as delays and slower travel times actually increase the driver's income for the same load.

The relationship between payment and safety is also not new. The Australian Transport Workers' Union (TWU) has long lobbied for 'safe rates'. Of particular note, the TWU placed a submission to the Road Safety Remuneration Tribunal arguing that drivers are often not paid for waiting times, and feel pressured to speed (Transport Workers' Union, 2012). Past research has also supported the link between payment and safety. Belzer, Rodriguez and Sedo (2002) found that within the USA's heavy vehicle industry higher levels of payment were associated with lower crash rates. Williamson (2007) found that Australian heavy vehicle drivers were more likely to use illegal stimulants if they were paid a distance rate, or were paid below the award rate. Further, Williamson and Friswell (2013) found that incentive payment, particularly where there is no payment for waiting time, was associated with increased hours worked, kilometres travelled and greater levels of fatigue among Australian long-distance truck drivers. The current findings support the need for pay which doesn't provide an incentive to speed. The findings from this study add to the arguments that the TWU have offered, and show similar trends to that which Williamson revealed with stimulant use and fatigue, indicating that regardless of the amount of pay received, payment per km gives incentive to travel faster and avoid delays. Thus to limit the incentive to speed, it is recommended that distance and load based payment be eliminated in favour of an hourly payment.

The second series of interactions were based around the priority drivers give to safety and the tendency for drivers to learn what is safe through experience and stories. The findings highlighted that drivers can be vulnerable to normalisation of deviance (Vaughan, 1996). When this occurs, resulting in drivers viewing speeding as safe, they will seek to avoid punishment through either driving at the legal speed limit when in the presence of police enforcement, or speeding while avoiding detection. Existing monitoring techniques were found to be insufficient to regularly detect and deter speeding. While there is a need to improve these methods of monitoring, without passing legislation to download vehicle data, or force organisations to monitor speed in all zones, it may be difficult to truly ensure speeding doesn't go undetected and develop sufficient deterrence. However, as was briefly indicated, it may be possible to increase internal motivation to drive at a safe speed through the use of speed-related incident reports in training. There is a clear need to ensure drivers have a firm belief that speeding is dangerous. While this

study indicates that the use of stories could be a beneficial method to improve compliance it is not clear how this could be directly applied. Further research is needed to identify effective methods through which to increase the perception of danger associated with speeding.

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A road safety risk prediction methodology for low volume rural roads

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Winner of the John Kirby Award for best paper by a new researcher at the Australasian Road Safety Conference ARSC2015

Abstract

The roads of New Zealand's Eastern Bay of Plenty region have relatively low vehicle volumes and experience a number of rural road safety issues, including inappropriate speed, the use of drugs and alcohol, low levels of restraint use and young/inexperienced drivers. Over half of all rural crashes are loss-of-control crashes on curves. Due to low network traffic volumes, crashes tend to be sporadic and difficult to predict using risk assessment techniques that rely on crash histories.

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

The new methodology extracted and classified almost 7000 curves across 1500km of road network. When compared to the location of loss-of-control crashes, it was found that 66.6% of crashes occurred on 20.3% of curves classified as 'high risk' in at least one direction. These results have been

shared with road controlling authorities and will support prioritised road safety improvements targeting high risk curves.

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

Introduction

Safer Journeys, New Zealand's Road Safety Strategy 2010-20, has a vision to provide a safe road system increasingly free of death and serious injury (Ministry of Transport, 2010). This Strategy adopts a safe system approach to road safety focused on creating safe roads, safe speeds, safe vehicles and safe road use. These four safe system pillars need to come together if the New Zealand Government's vision for road safety is to be achieved.



Figure 1. Eastern Bay of Plenty locality map

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

The Eastern Bay of Plenty region (Figure 1) was identified as a candidate for a safe systems signature project as it is a region with significant rural road safety issues; particularly inappropriate speed, use of alcohol/drugs, poor restraint use and inexperienced drivers. The scope of the project includes rural State highways and local roads. Most Eastern Bay of Plenty roads are low volume remote roads, where crashes tend to be sporadic and difficult to predict using reactive crash prediction models. Therefore a new approach to assessing road risk, independent of crash history, was required.

Abley Transportation Consultants was commissioned by the New Zealand Transport Agency (the Transport Agency) to develop a risk prediction model and mapping interface “SignatureNET” to support the delivery of this signature project. This included building a vehicle speed model to identify high risk curves, assessing road risk using the urban KiwiRAP risk mapping methodology (Brodie et al., 2013), and applying rural road risk prediction models.

Methodology

Many rural road crashes in Eastern Bay of Plenty occur on curves (57.9% of all fatal and serious rural road crashes 2004-2013) (NZTA, 2014). Due to the remote nature of the region’s roads, fatal and serious crashes tend to occur on parts of the network where high-severity crashes have not occurred in the recent past. In these areas, relying on crash

history alone to predict where future crashes will occur is unreliable. A new methodology that could identify and assess the risk of all the curves on the network that was independent of crash history was developed.

The Austroads (2009) operating speed model for rural roads provides a procedure for calculating speeds along road sections based on the geometric features of the road. Using calculated speeds and horizontal curve radii, the model allows users to assess the design limit of curves.

With 1500 km of rural road, manually assessing the risk of each curve in the Eastern Bay of Plenty region using the Austroads model would be time-consuming and cost-prohibitive. As the inputs to the Austroads operating speed model are available in a spatial format, the model was therefore automated using a new Geographic Information Systems (GIS) methodology. This included the development of GIS models that identify curves, predict vehicle operating speeds along road corridors, and assess curve risk using approach speeds and radius (Harris & Durdin, 2015). This methodology is discussed, in brief, below.

Curve identification

The first step in speed modelling methodology is to identify curves using a high quality road centreline and a methodology adapted from Cenek et al. (2011). The spatial road dataset used in this methodology closely matched the actual centreline of the road. Using GIS linear referencing tools, the road centreline was divided into 10m sections and the rolling 30m average radius calculated for each arc section.

Discrete curve sections were extracted by combining road segments where:

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

Contiguous 10m sections of road that met these criteria were dissolved into a single curved segment, with the radius (m) of the curve defined as the minimum radius across all the sections that make up the curve. The calculated curve radii represents a mid-road curvature value (rather than separate curve radii values for each lane or direction), noting that there are no divided carriageway roads in the Eastern Bay of Plenty region.

Speed modelling

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

Once curves had been identified, each road corridor was divided sequentially into a series of curves with known radii, and straights with known lengths. Speeds were then modelled along the road centreline in both directions. Sections of road with curves of a similar radius separated by short straights (less than or equal to 200m) were identified as discrete sections with an operating speed identified within a narrow range of values (minimum and maximum operating speeds). When drivers travel through a series of curves with a similar radii, their speeds stabilise to a level they feel comfortable with (Austroads, 2009). Section operating speeds for single, isolated curves were also calculated.

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

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

Rates of acceleration and deceleration were modelled using the methodology in Austroads (2009) (Figures 2 and 3). Extrapolation of values was required to estimate some acceleration and deceleration outputs, including acceleration for straights longer than 1000m (Figure 2) and

deceleration where curve approach speeds are less than 60 km/h (Figure 3).

The exit speed at the end of each curve or straight is applied as the approach speed for the following section of road. For each curve where deceleration is modelled, the design limit is identified as either out-of-context (unacceptable or undesirable) or within context (desirable) (Figure 3). Curves where no deceleration is modelled are also considered to be ‘within limit’.

Results

The curve identification methodology recognised 6,985 curves across the Eastern Bay of Plenty region. Each curve was classified by design limit (in both directions) according to the Austroads speed model (Figure 3). The number of curves identified by category are displayed in Table 1. Where curves were classified differently in opposing directions, the worst (most out-of-context) classification has been applied. For example, a curve that is ‘undesirable’ in one direction but ‘within limit’ in the reverse direction would be categorised as ‘undesirable’.

Because the curve identification methodology developed for this project was new and untested, the results were compared against an existing Transport Agency curve dataset for the state highway network in the Eastern Bay of Plenty. The state highway curve dataset is based on horizontal curvature data collected in the field as part of the Transport Agency’s annual high speed surveys (Cenek et al., 2011).

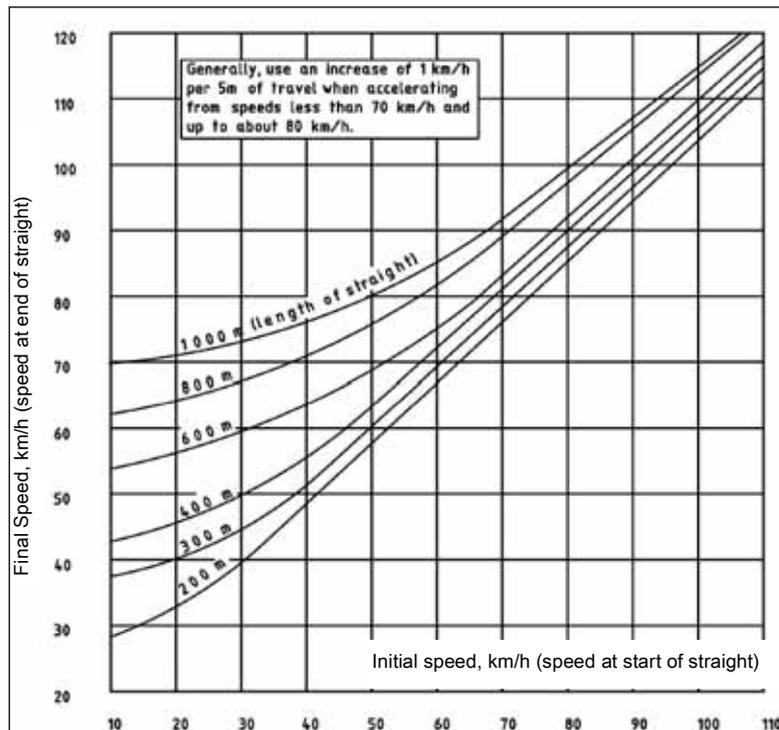


Figure 2. Acceleration on straights (source: Austroads, 2009)

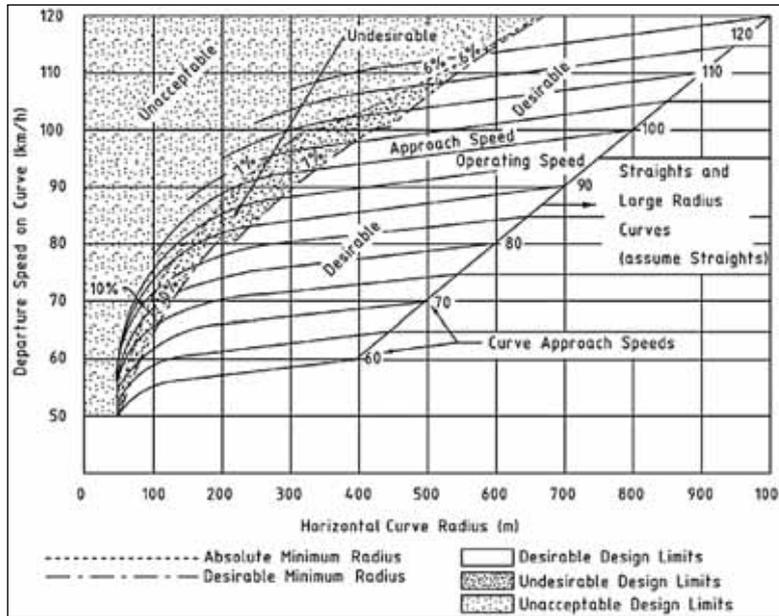


Figure 3. Deceleration on curves and design limits (source: Austroads, 2009)

Table 1. Eastern Bay of Plenty curve categorisation

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

The new methodology identified the location of 96.8% of curves in the state highway dataset, with a visible correlation between curve radii values (Figure 4). The two datasets met the assumptions required for linear regression, with 82% of calculated curve radii values within 20% of the Transport Agency’s curve radii values. The degree of scatter between the two datasets, particularly for large-radius curves, is primarily attributed to the different collection methods. The state highway dataset is collected in-field using lane-based radii, whereas the operating speed model methodology relies on radii values calculated from the centreline. Extreme outlier values are more likely to reflect errors in the geometry and topology of the road centreline dataset.

The results of the curve analysis were delivered through a mapping website (“SignatureNET”), which displayed the risk metrics alongside contextual road safety data including administrative boundaries and crash locations (Figure 5).

Correlation between curve category and loss-of-control crashes

Further analysis was undertaken to identify the number and percentage of loss-of-control crashes by curve category. For this comparison, 10-years of crash data (2004-2013) was

selected from New Zealand’s Crash Analysis System (CAS) (NZTA, 2014a). For the purposes of this analysis, loss-of-control crashes were defined as those with movement code ‘BF’ (head on - lost control on curve), ‘DA’ (lost control turning right) or ‘DB’ (lost control turning left) in CAS (NZTA, 2014b).

In the 10-year period selected, there were 589 loss-of-control crashes on the curves categorised using the curve risk assessment methodology. The number and percentage of loss-of-control crashes by curve category are presented in Table 2.

Table 2. Eastern Bay of Plenty loss-of-control crashes by curve category

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

The results show that two thirds (66.6%) of all loss-of-control crashes occur on out-of-context curves i.e. those identified as ‘unacceptable’ or ‘undesirable’. This is a particularly important finding as it means road controlling authorities in the Eastern Bay of Plenty can target efforts on 20.3% of all curves where 66.6% of all loss-of-control crashes occur.

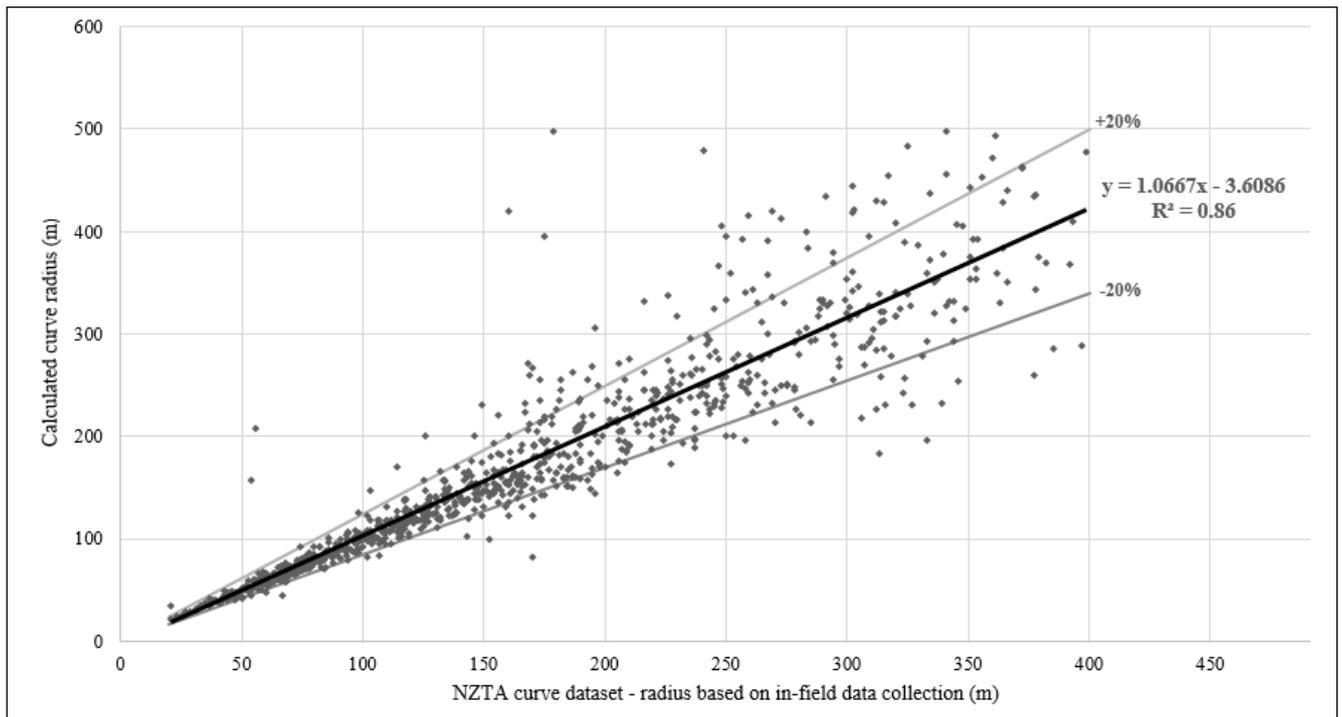


Figure 4. Comparison of calculated curve radii against NZTA out-of-context dataset

Further analysis and model validation

Since the first development of the operating speed model for the Eastern Bay of Plenty, the operating speed model has been applied to the Top of the South region of New Zealand - the area encompassed by the South Island local authority districts of Marlborough, Tasman and Nelson City. It includes some 3382 km of rural roads, which is much larger than the Eastern Bay of Plenty region (approximately 1500 km).

The operating speed model identified a total of 21,158 curves in the Top of the South region. The results of the curve classification are displayed in Table 5, showing that the proportion of curves in each classification in the Top of the South region mirrored the Eastern Bay of Plenty region (Table 3) very closely.

Table 3. Top of the South curve categorisation

Curve Category	Total Curves	% of all Curves
Unacceptable	1772	8.4%
Undesirable	2215	10.5%
Desirable	2345	11.8%
Within Limit	14826	70.1%

Analysis of loss-of-control crashes against curve category was also undertaken for the Top of the South region, identifying that 55.8% of all loss-of-control crashes occurred at 18.9% of curves identified as out-of-context ('unacceptable' or 'undesirable') (Table 4). This result is similar to the analysis of the Eastern Bay of Plenty region, although the correlation is not as pronounced.

Table 4. Top of the South loss-of-control crashes by curve category

Curve Category	Total LOC Crashes	% of all LOC Crashes
Unacceptable	360	32.3%
Undesirable	262	23.5%
Desirable	135	12.1%
Within Limit	359	32.2%

The Eastern Bay of Plenty and Top of the South data were combined so the relationship between curve categorisation and loss-of-control crashes could be better understood (Figure 6). This figure shows there is a strong relationship between curve category and loss-of-control crashes. The relationship indicates that focusing road safety improvement efforts on out-of-context curves is targeting to risk.

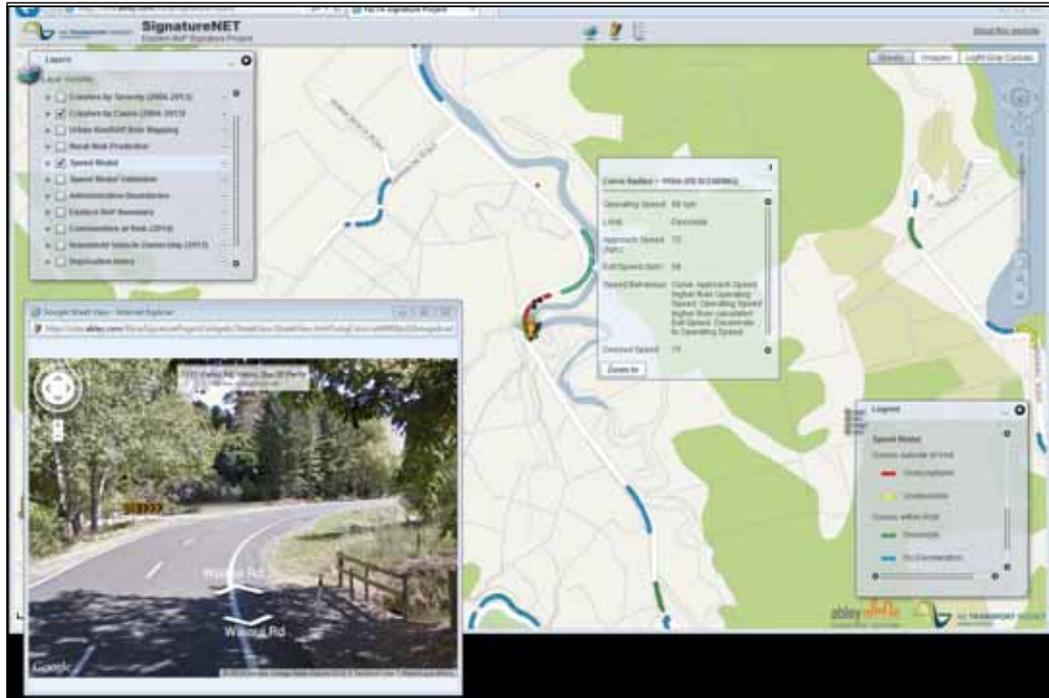


Figure 5. SignatureNET mapping website screenshot

Discussion

The methodology presented in this paper has been well-received by all the agencies involved in the delivery of the Eastern Bay of Plenty safe systems signature project. The curve risk data and SignatureNET web viewer is now available to all the local road controlling authorities to assist them in identifying and prioritising road safety interventions targeting loss-of-control crashes on curves.

Current applications

The curve assessment and automated operating speed model is currently being rolled-out across other locations in New Zealand.

Informing speed management decisions

The Transport Agency has developed a process for identifying parts of the state highway road network for speed management interventions based on road safety risk. Potential interventions include targeted enforcement, reducing speed limits, or upgrading parts of the road network to reduce the frequency and severity of crashes at current operating speeds. To determine and prioritise appropriate intervention strategies, the operating speed model was applied across the high speed state highway network to determine: (a) operating speeds under current speed limits; and (b) operating speeds under the identified safe and appropriate speed limits, noting that speed limit is a factor in determining the maximum (desired) speed of a road (Austroads, 2009; Harris & Durdin, 2015).

The different operating speeds are then being used to estimate the potential for death and serious injury (DSi) savings by using Nilsson's Power Model which connects changes in traffic speeds with changes in road crashes at various levels of injury severity using a power relationship (Nilsson, as cited in Cameron & Elvik, 2008). Sections of state highway that exhibit little or no speed reduction are considered to be 'self-explaining' as the geometry and terrain of the road naturally prevents drivers from achieving higher speeds. Conversely sections with extreme differences when comparing the current operating speeds and the safe and appropriate operating speed are generally straight roads where enforcement or engineering improvements may be more appropriate, depending on potential DSi savings and the functional classification of the corridor.

Training safety practitioners

As noted earlier, the methodology has been extended to the Top of the South region in New Zealand for exercises in the annual Safe Systems Engineering Workshop. The outputs were presented in a web viewer and combined with Urban KiwiRAP risk profiles for the region delivered as part of an Accident Compensation Corporation (ACC) funded road safety initiative. The web viewer was used as learning media to introduce Safe Systems Engineering Workshop attendees to the use of network screening tools to assist with the identification of road safety issues across the region. By considering different risk metrics alongside one another and in combination with crash data, practitioners were able to identify potential factors contributing to high-risk locations and formulate responses at a desktop level prior to physically investigating sites.

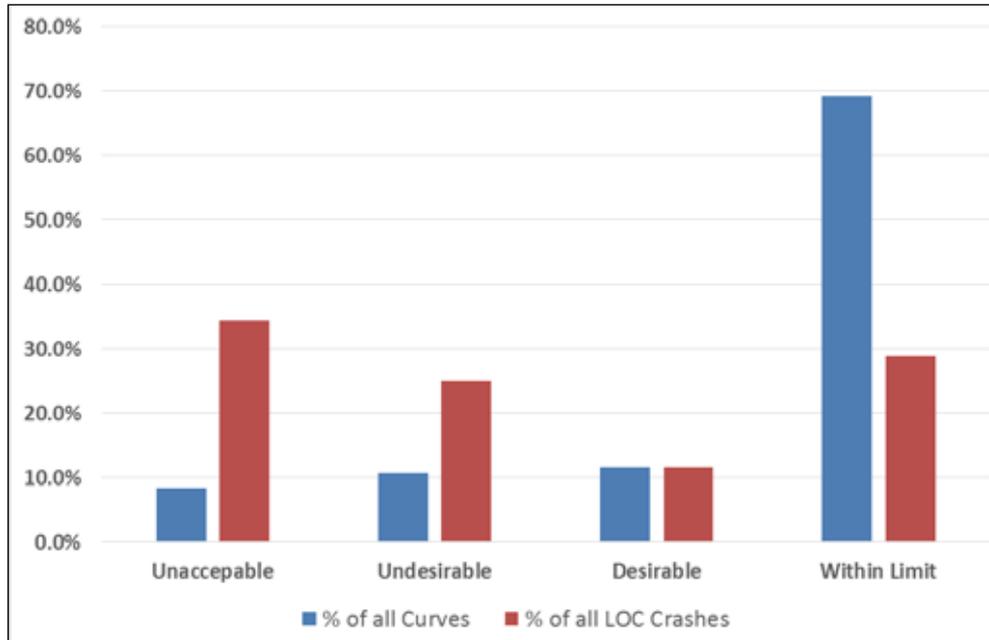


Figure 6. Graph demonstrating the relationship between curve category and the location of loss-of-control crashes

Limitations and future enhancements

The speed modelling and curve risk assessment methodology is of greatest value to road safety practitioners where it is used as a network screening tool. The methodology should be applied with care when considering individual curves. Site-specific factors such as roadside hazards should be taken into account when identifying or prioritising curve treatments. For this reason, the SignatureNET web viewer included aerial imagery basemaps, Google Street View and other contextual data to support users in undertaking desktop reviews.

During the development and roll-out of the methodology, a number of further enhancements were suggested and are being explored. These include:

- a. Enhancing the speed model by exploring the relationship between curve risk category, road surface type, carriageway width and actual road safety performance.
- b. Exploring the relationship between curve risk category, KiwiRAP star rating and the road safety performance of state highways.
- c. Enhancing the speed model by comparing calculated operating speeds against known operating speeds, for example data collected using GPS devices.
- d. Exploring the feasibility of using high-resolution elevation data collected using LiDAR, (if available) to calculate super elevation and vertical curvature and incorporate these factors into the curve risk assessment models.

Conclusion

The operating speed model and high risk curve assessment methodology demonstrate that innovative assessment methods and tools can be developed within a safe system signature project environment. Current applications of this methodology in New Zealand demonstrate the potential of this methodology in supporting the safe system philosophy, including the identification of high risk curves for targeted safety investigation and treatment (Eastern Bay of Plenty), supporting the development of the New Zealand Transport Agency’s Speed Management Guide, and being used as training media for Safe Systems Engineering Workshops. The curve identification and analysis techniques presented in this paper will be of particular interest to any road controlling authorities wanting to reduce loss-of-control crashes on rural roads.

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Laser ablated removable car seat covers for reliable deployment of side airbags

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This paper is an extended version of an earlier conference paper that was presented at the ARSC 2015. It has undergone further extensive peer review; revised with additional material added.

Abstract

In the event of a collision, the safe and reliable deployment of side airbags which include side-torso and combination airbags through removable car seat covers that use tear-seam technology has been recently questioned. It is well known that a side-torso airbag system in automotive seats can reduce injuries and prevent fatalities in the event of a collision. Removable car seat covers suitable for side airbag systems are popular accessories in the automotive industry from the perspective of upholstery protection and aesthetics. This study demonstrated a better-suited technology in which laser ablation down the side panel of removable car seat covers, produced a pre-determined strength within a weakened zone that allowed a reliable airbag deployment in the event of a collision. This paper investigates the effect of laser power as a key factor in the laser ablation process and its influence on the bursting strength of the car seat cover materials. The laser-ablation of the removable car seat covers can ensure the consistent airbag deployment under environmental conditions and temperatures ranging between ambient ($22 \pm 2^\circ\text{C}$), cold ($-35 \pm 2^\circ\text{C}$) and hot ($85 \pm 2^\circ\text{C}$). The durability and deployment performance of these car seat covers after UV exposure was also investigated.

Keywords

Laser ablation, Textiles, Car seat covers, Side-torso and combination airbags, Bursting strength

Introduction

Airbags in passenger vehicles are a supplementary restraint system to seat belts that further mitigates the injuries suffered in serious crashes. The use of airbags can help to minimise the chances of fatalities from an external collision, and limit passenger impact with the inside of the car. Airbags were first introduced in passenger cars by Ford in 1971 to protect the driver and front passenger in frontal collisions. Since then, the number of airbags in modern cars has increased to five and in some cases to nine; covering a wide range of accident scenarios. Side airbags were first introduced into vehicles around 1995 to help protect passenger car occupants from serious injury in struck side crashes. International studies have shown that side airbags that include side-torso as well as head-and-torso (combination) airbags are effective in reducing the risk of death in near side impact situations, and mitigate injuries in vehicle rollovers (Braver, 2004; D'Elia, 2012). A driver involved in a side impact has twice as high a fatality risk as a driver involved in frontal impacts (Farmer 1997). In 2014 in Australia, 1299 passenger vehicles were involved in police-reported fatal crashes. These crashes resulted in 763 deaths (BITRE, 2014).

Airbags in front occupant car seats are generally concealed in a moulded plastic enclosure contained within the side upholstery of the seat as either a combination or torso-only system. The seat upholstery through which the side airbag would deploy involves a tear-seam technology that facilitates the inflation of the airbag during a collision.

For a moving vehicle, frontal airbags primarily deploy for crashes at speeds of 20-30 km/h (Toyota, 2015). When an internal accelerometer senses a possible collision, a microprocessor senses the vehicle deceleration and other relevant parameters and initiates the deployment of the airbag (Huffman, 2011). At the time of deployment, the airbags release by rupturing the moulded plastic enclosure within the seat, followed by bursting of the tear-seam of the upholstery of the fitted seat. The airbag deployment is executed with an enormous velocity of 200 – 320 km/hr (Braver, 2004; Farmer, 1997).

The use of removable car seat covers over the standard upholstery is a popular accessory used to protect the upholstery as well as to give aesthetic appeal. Similar to the car seats, the removable seat covers also include a tear seam along the side gusset to enable the deployment of the airbag during a collision. It is imperative that the seat cover never obstructs the full deployment of the airbag.

Our research has identified that current seat cover designs that employ tear-seam technology have issues of reliability and predictability during airbag deployment, due to various technical and design deficiencies in the tear-seams. Several factors such as fabric stretch, the strength of sewing thread used at the tear-seam, the length of the tear-seam, the placement of the tear-seam, the type of stitch, and stitch density can affect the behaviour of airbag deployment. As a consequence, ballooning of the seat cover material prior to the failure of the seam can occur which increases the time taken for the airbag to deploy, thus reducing its effectiveness.

Laser processing in the automotive industry for applications such as cutting, drilling, marking, welding and the surface treatment of materials such as ceramics and plastics is well established (Roessler, 1989). In the textile industry, laser processing has been used extensively for cutting of fabrics (Jackson, 1995); engraving designs on fabrics (Yuan, 2011) and carpets, surface modification of fabrics, decorative finishes on denim (Ortiz-Morales, 2003), and wool felting (Nourbakhsh, 2011). The laser technologies used in these industries usually employ CO₂ and neodymium-doped solid-state lasers. In textile manufacturing, CO₂ lasers are predominantly used with typical operating power efficiencies in the range of 5 – 15% and maximum continuous power outputs well over 10 kW. For comparison, solid-state lasers are characterised by much lower power efficiencies and are operated in a pulse mode. The wavelength of the emission from a CO₂ laser is about 10 µm, whereas the neodymium-doped laser is often characterised by an emission wavelength centred at 1.06 µm, a factor of 10 shorter than that from CO₂ but still in the infrared region.

The use of laser processing to facilitate cutting in a predetermined pattern for strategic weakening of car interior door panels that cover the exit points for airbags has been explored by Riha et al. (Riha, 2006). Similarly, Bauer researched the use of a controlled laser beam to weaken the back of the cover layer of trims of a car interior by wholly cutting through the substrate and partially through the

cover layer to produce grooves of a precise depth and width (Bauer 2001). Costin investigated the application of laser technology to impart patterned designs on thin fabrics and leather by using an electronic controller to direct the drive mechanism for controlling the speed of etching (Costin, 2000).

The concept of using lasers to pre-weaken the side panel of a removable car seat cover has not been explored until now. Laser processing for such applications required the development and demonstration of pre-weakened fabrics to allow for reliable, predictable and timely deployment of airbags through the tearing of the fabric cover. While many of the above authors have attempted to modify fabric surfaces using lasers to allow for deployment, the concept of pre-weakening a precise zone to a known bursting strength has not been demonstrated.

There are several challenges that can be encountered when using the pre-weakening concept on removable car seat covers. Unlike fixed trims and face fabrics that are adhered to the foam of the car seat (as in the case of OEM car seats), removable car seat covers can distort and result in significant misalignment from the actual deployment zone which can create serious performance issues. The objective of this research was to develop a pre-weakened and predetermined zone having a known bursting strength for facilitating reliable side airbag deployment from a car seat.

Experimental method

Fabric material

A 100% polyester weft knitted textile fabric supplied by Who-Rae Pty Ltd was used for the experimental investigations. The fabric properties are as shown in Table 1.

Table 1 Fabric material specifications

Parameters	Details
Yarn used	100 % Polyester
Yarn count	100 denier
Mass per unit area	100 g/m ²
Courses/cm	9
Wales/cm	10

Laser ablation of fabric

Laser ablation of the fabric was performed using a commercial CO₂ laser in atmospheric conditions. The generated wavelength of the laser beam was set at 10.6 µm and the laser power was set at 80 - 150 W. The applied laser etching software was LaserCut[®] and laser engraving on the fabrics involved pattern files designed using Adobe Photoshop[®] graphics design software. The JPEG files were created in grayscale. The fabrics were placed in an etching cabinet for the laser treatment at different intensities by varying the process parameters.

The controlled laser has three operational parameters that were varied to control the ablation of lines of weakness on the fabric namely power; the distance between the ablated lines; and the angle of the lines. The intensity of the laser was optimised by changing the scale of power incrementally from 1 to 20 %; where the intensity of the ablation increased with higher laser power; and adjusting the distance between the lines.

Performance assessment of the laser ablated fabric material

Static airbag deployment testing

Static airbag deployment testing was conducted at a NATA accredited airbag testing facility - APV Engineering and Testing Services, Melbourne. The airbag deployment testing was carried out under different environmental conditions which included ambient ($22 \pm 2^\circ\text{C}$), cold ($-35 \pm 2^\circ\text{C}$) and hot ($85 \pm 2^\circ\text{C}$) temperatures.

Bursting strength

The bursting strength of the laser ablated fabrics were evaluated using an SDL Atlas Autoburst® M229 hydraulic bursting strength instrument in accordance with ASTM D3786 standard test method (ASTM, 2001). Ten specimens of each of the experimental fabric samples were tested. The specimen size was 15 cm x 15 cm.

Accelerated UV exposure

A UV exposure test was conducted in accordance with SAE J2412/ J2413 (SAE, 2012). A Ci400 Weather-Ometer was used for this test. Laser ablated fabrics were exposed to 263 kJ/m^2 of UV radiation. The UV exposed samples were subsequently tested for bursting strength.

Results and discussion

Airbag deployment tests for tear-seam technology based seat covers

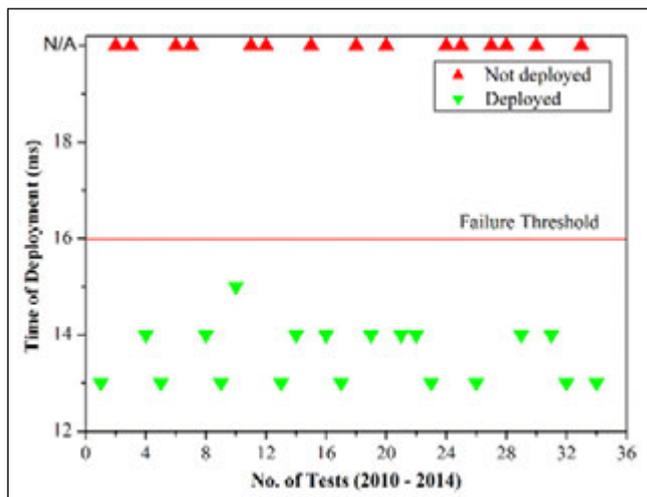


Figure 1 Airbag deployment testing of car seats covers with tear seam technology

Random batch testing to determine the reliable airbag deployment through seat covers is a standard industry practice from a quality assurance perspective. Such tests are based on static airbag deployments and are commercially undertaken through an accredited laboratory. Results obtained from 2010 to 2014 are shown in Figure 1, and indicate that over 40% of side torso airbags failed to deploy through the tear-seam car seat covers. Investigation of these seat cover failures indicate the designs have issues of reliability and predictability due to various technical and design deficiencies in the tear-seams, such as fabric stretch; strength of sewing thread used in the tear-seam; length and placement of the tear-seam; type of stitch; and stitch density.

Effect of laser power on the bursting strength of fabric

Figure 2 shows the effect of power intensity of the laser on the bursting strength of the ablated polyester fabric. As the power intensity increased from 7% to 13%, the bursting strength of the fabric was decreased.

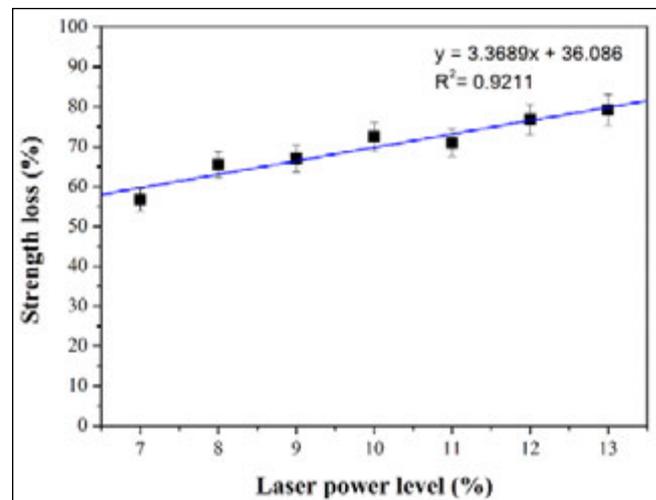


Figure 2 Relationship between laser power and bursting strength

In order to determine the optimal bursting strength of the laser ablated samples acceptable for timely deployment of an airbag, laser ablated fabrics of different power intensities were integrated into the cut-and-sewn car seat covers as side panels. These seat covers were subjected to static airbag deployment testing, initially at standard atmospheric conditions. Figure 3 shows a magnified image of the laser ablated pattern before (a) and after fabric bursting test (b), and Figure 4 shows the typical airbag testing before and after deployment.

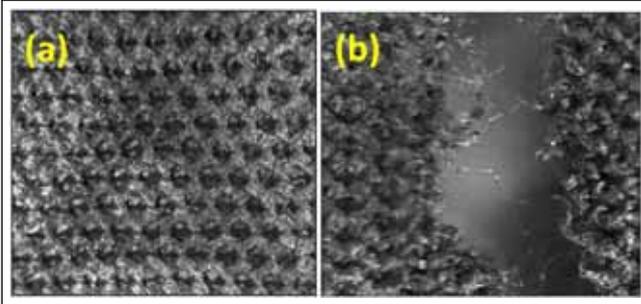


Figure 3 (a) laser ablated weakened area, (b) fabric tear at weakened area



Figure 4 Airbag deployment testing (a) side view before deployment (b) side view after deployment (c) front view before deployment (d) front view after deployment

Effect of bursting strength of laser ablated area on the airbag deployment time

Figure 5 shows the relationship between the bursting strength of the laser ablated area in the pre-weakened zone of the polyester fabric and the airbag deployment time. The average time of deployment for a standard side-torso airbag to extend 50 mm, 150 mm and full extension can be estimated to be around 3 ms, 7 ms, and 15 ms respectively (Balavich, 2011). The industry-accepted failure threshold for side airbag systems is set at 16 ms, during which time an airbag is expected to be fully deployed. To pass the acceptable threshold therefore, the deployment time through the seat upholstery and the additional seat cover must be below this failure threshold to ensure reliable deployment of the airbag.

From Figure 5 it is observed that timely airbag deployment can be achieved when the strength of the laser ablated fabrics is reduced by approximately 70% from its original strength. The airbag deployment time however exceeds the failure threshold of 16 ms when the bursting strength reduction is less than 60%. If the reduction in bursting strength is greater than 80%, the durability of the fabric is compromised and premature tearing of the side panel may occur. According to Figure 5, if the strength is reduced by 60% from the original, the samples may pass the standard but the fabric may not be sufficiently weakened for a deployment if the temperature in the car exceeds 22 °C.

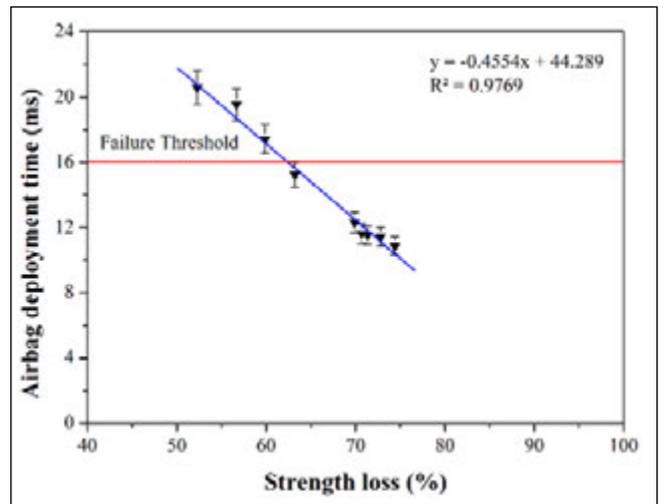


Figure 5 Relationship between bursting strength of laser ablated area and airbag deployment time at ambient conditions

The laser ablation showed an obvious effect on the bursting strength, when the strength was reduced to approximately 25% of its original strength.

Effect of environmental condition on airbag deployment time

Car seat covers are used in different geographical locations where the environmental conditions can be extreme. In order to investigate the performance of the car seat covers with the laser ablated pre-weakened side panels, the seat covers were subjected to hot (85 °C), cold (-35 °C) and ambient (22 °C) environmental testing conditions. Figure 6 shows the effect of different environmental conditions on the deployment efficiency and time for the car seat covers with pre-weakened laser ablated side panels. The results showed a slight increase in the deployment time with increase in temperature but were within the failure threshold. This change is due to the increase in the polymer elasticity which would increase with temperature.

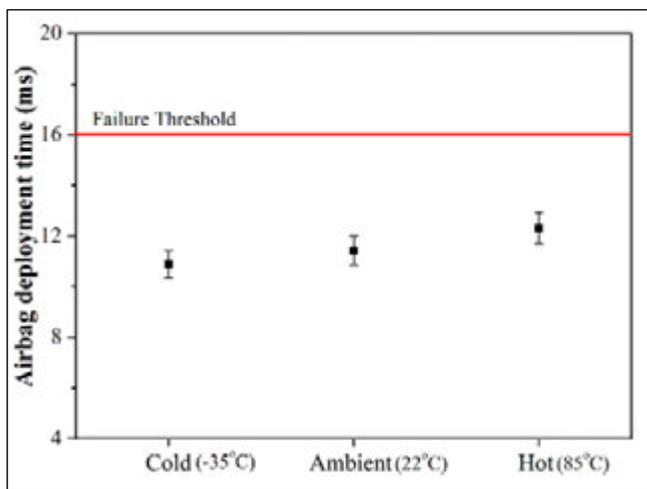


Figure 6 Effect of environmental condition on airbag deployment time of laser ablated car seat cover

Effect of UV exposure on bursting strength of laser ablated area

Based on the requirements of the automotive industry, an assessment of the performance of upholstery and removable car seat covers when exposed to UV radiation must be made to determine the lifetime durability. This parameter was investigated in accordance with the SAE J2412/J2413 standards. Figure 7 shows the effect of UV irradiance on the bursting strength of the laser ablated pre-weakened side panel. The laser ablated fabric panels exposed to UV irradiance intensities of 38 kJ/m², 75 kJ/m² and 263 kJ/m² were tested for bursting strength and static airbag deployment respectively. The fabrics exposed to 263 kJ/m² UV radiation showed less than 10% reduction in the bursting strength. This is deemed to be acceptable because the strength of the fabric is expected to degrade over time due to the ageing effects of heat and UV.

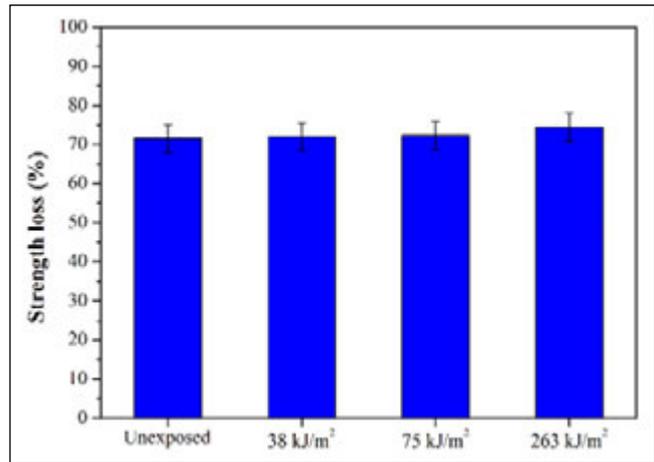


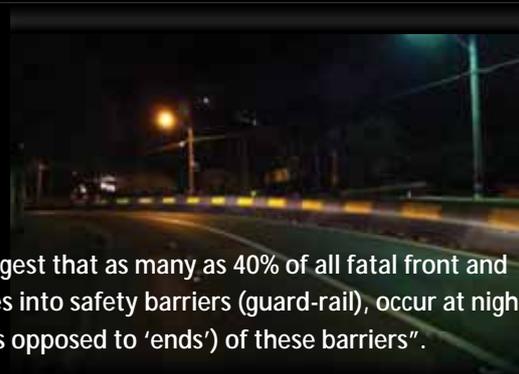
Figure 7 Effect of UV irradiation on the bursting strength of laser ablated area

Conclusions

Laser ablation can be applied to develop a pre-weakened zone in a car seat cover for reliable deployment of side-torso or combination airbags. Laser ablation offers the advantage of being able to adjust the level of weakness of the deployment zone to guarantee 100% efficiency. Current tear-seam technology relies on the quality of the sewing operation and the materials used, and as a consequence this may result in as many as 40% of tear seams not performing as required. For the chosen fabric, the current research has shown that for timely and efficient deployment, the optimum bursting strength of the laser ablated fabric should be reduced to 25% of its original. This is likely to change for different fabrics and therefore it is recommended that the optimal bursting strength of individual fabrics be determined. The performance of the laser ablated car seat covers tested under various environmental (-35°C, 22°C, and 85°C) conditions, showed an increase in deployment time as a function of increase in temperature, but did not compromise the effective operation of the pre-weakened zone. Laser ablated fabrics exposed to UV irradiance of 263 kJ/m² showed a reduction of less than 10% in bursting strength which means its life-time should only be marginally compromised.

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Contributed articles

Heavy vehicle driver fatigue: evidence-based policy making

by Marcus Burke, James Williams and Dr Nick Fischer

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Information based on a presentation given at the Australasian Road Safety Conference (ARSC2015), 14 – 16 October, Gold Coast, Australia

Abstract

This article introduces a new National Transport Commission project, undertaken in collaboration with the National Heavy Vehicle Regulator, to develop a national framework to collect and analyse fatigue data by the end of 2016. Historic challenges associated with reforms of the national heavy vehicle fatigue regulations are highlighted; and in particular the need for an improved evidence-base before further amendments of fatigue laws are considered. For example, agencies today are collecting enforcement and crash investigation data using different processes and formats. This limits opportunities to collate and compare meaningful fatigue data and an initial step would be to standardise fatigue reporting. From this foundation, a number of improvements can be made. For example, one improvement could involve recording in a standardised format when a driver in a fatigue-related crash is accredited in a government scheme that permits more than “standard” hours of work.

The NTC has developed a list of priority fatigue issues, as well as data collection and research options. The framework aims to improve roadside enforcement data collection, improve and standardise crash investigation reporting and crash codes, and to undertake scientific research in partnership with the Alertness CRC.

Drawing on fatigue expert advice, Alertness CRC research activities and submissions to the NTC discussion paper (published for consultation on 21 August 2015), an explanation is given on how the framework can measure and improve the understanding of fatigue impairment in a number of areas, including:

- frequency and impact of higher-risk driving schedules
- sleep quality and quantity of sleep in rest breaks
- impact of night driving and;
- health and well-being of heavy vehicle drivers.

An appraisal of some risks and challenges associated with data collection and fatigue research is included.

Introduction

Since the introduction of heavy vehicle model laws in Australia in 2008, a number of measures, including a general duty not to drive while impaired by fatigue and Chain of Responsibility obligations on third parties, have contributed to a reduction in crashes involving heavy vehicles. However, crash statistics and driver attitudinal surveys indicate that driver fatigue remains a significant contributor to the road toll.

Drivers of vehicles over 12 tonnes (or buses over 4.5 tonnes with capacity to carry 12 or more people) are regulated by the Heavy Vehicle National Law (HVNL) in all Australian jurisdictions except Western Australia and the Northern Territory. The HVNL is administered by the National Heavy Vehicle Regulator (NHVR). This is a significant national law reform, not only enabling a single rule book across jurisdictions, but providing a framework to standardise data collection, for both enforcement and research purposes.

The HVNL has five key tools to reduce driver fatigue:

1. Duty of driver to avoid driving while fatigued
2. Duty of third parties to ensure business practices will not cause driver to be fatigued
3. Advanced Fatigue Management (AFM) within a safety management system approach
4. Maximum work and minimum rest rules: up to 12 hours work in 24 hours for drivers on standard hours, and 14 hours in 24 under Basic Fatigue Management (BFM) and;
5. Work diary record keeping.

These are supported by work safety principles, operational practices and industry schemes.

Heavy vehicle driver fatigue is a complex policy area and the impact of these regulations on driver fatigue is not definitive; particularly the effectiveness of the work and rest rules. There is also an opportunity to standardise how data is collected through enforcement activities, crash investigations and surveys.

Without improvements to data collection, supported by robust and validated research, the underpinning evidence is not available to support further fatigue reforms. For this reason, in November 2014 the Transport and Infrastructure Council, an organ of COAG, endorsed the NTC and NHVR to develop within two years a national framework to collect real-life operational data to better inform broader fatigue policy directions in the future.

In early 2015, the NTC surveyed road agencies, police and industry to benchmark current data collection processes and to capture preliminary fatigue issues that could be addressed in the framework. In August 2015, the NTC released the *Heavy Vehicle National Fatigue Data Framework discussion paper* for consultation. This paper identifies and prioritises regulatory fatigue issues, sets out framework principles, and proposes data collection and research activities. This includes consideration of new heavy vehicle crash investigation processes.

The NTC will make recommendations to the Transport and Infrastructure Council in 2016.

Road agency and police perspective

Governments support development of a data framework. Three significant issues were raised:

1. **Length of the major rest break.** A driver on standard hours must have a seven hour major rest break in a period of 24 hours. Fatigue research recommends that between 5-8 hours of sleep is required per night, depending on individual biology. Better data is sought to measure sleep quality and quantity in major rest breaks and to assess whether there is sufficient sleep opportunity in a major rest break of seven hours.
2. **Additional hours of work under BFM.** Better data is sought to assess whether the additional two hours a BFM driver can work is sufficiently off-set with current counter measures (including reduced night shifts). An assessment of the counter-measures could also be linked to a validation of the AFM risk classification system.
3. **Nose-to-tail schedules.** Under the current counting rules that determine when a 24 hour period commences, data is sought to measure the fatigue impact from allowing two long periods of work in a 24-hour period (separated by a major rest break).

Industry perspective

In early 2015, the NTC developed multiple-choice and free-text survey questions with input from the Australian Trucking Association (ATA) and NatRoad. The survey was hosted on survey monkey and made available on the NTC website. The survey was also promoted by the ATA and NatRoad. The survey established a baseline of what fatigue, crash and incident data operators collect and what operators do to assess fitness to work. The survey also identified fatigue issues and options from an industry perspective.

There were 107 respondents. Over half the respondents were operators, a quarter were drivers and less than ten were trade associations. One respondent was a freight customer. The results can only be considered indicative of industry views.

Respondents largely welcomed higher-quality data on crash incidents and near misses. A challenge identified was operator reliance on manual systems, driver interviews and observational information to assess driver fatigue. Only around a fifth of respondents reported using outward and inward-facing camera and other technologies.

Highly-rated factors contributing to fatigue from an industry perspective was poor fitness for work, especially pre-trip fatigue caused by insufficient sleep and rest during a long rest break. Other contributing factors rated highly by respondents included the availability and quality of rest stop areas and the quality of sleep obtained on a driver's rest break. Around a third of respondents also regarded a driver's work schedule as a fatigue risk factor. Less than a fifth of respondents identified the length of the driver's rest break as an issue.

The importance of delays at distribution centres was raised as a factor that should be assessed for correlation with crashes and near misses. Another issue cited was the complexity of the fatigue laws which makes it more challenging to manage fatigue.

Fatigue expert advice

In March 2015, the NTC commissioned expert advice on the development of the data framework from the Centre for Accident Research and Road Safety, Queensland University of Technology, the Transport and Road Safety Research unit at the University of New South Wales, the Institute for Breathing and Sleep at Austin Hospital and the Appleton Institute, Central Queensland University.

Expert advice recognised fatigue risks with insufficient rest opportunities in the regulations, night driving (especially work periods that end between midnight and 6am), length of work opportunities and threshold issues relating to the exclusion of local work. Identifying whether there were adequate counter-measures in place to offset additional work permitted under BFM and AFM was also a significant issue.

In relation to the development of a data framework, experts advised that the framework needs to have clearly articulated high-level goals and specific objectives, with a clear implementation path to realisation. The data framework should be organised around collection of scientific evidence based on an agreed scale of fatigue impairment.

Proposed framework activities

Standardised crash investigation and reporting processes

Understanding the fatigue impact of HVNL regulations can be improved by standardising how fatigue impairment is identified and reported across Australian jurisdictions. There are three potential focus areas:

1. Standardised improvements to how crash investigators identify and categorise fatigue and alertness impairment as contributing factors, including the application of ‘fatigue likelihood’ and ‘fatigue impact’ scales. This would replace current yes/no fatigue reporting.
2. Standardised improvements to what data crash investigators collect from heavy vehicle drivers where fatigue had a likely impact. Current thinking in road agencies is that the following three questions standardised and collected are most critical:

1	Was the driver on standard hours, BFM or AFM?	_____standard/BFM/AFM
2	When did the driver wake up from the last sleep?	_____time since wake up
3	How much sleep did the driver have in the last 24/48 hours?	_____hours

3. Review the Australian Transport Safety Bureau operational definition of relative fatigue.

Collection and analysis of work diary records based on activities identified during compliance and enforcement activities

Police and road agencies interact with heavy vehicle drivers through compliance and enforcement activities. These interactions provide an opportunity to collect improved fatigue data. Under this proposal, national processes are developed to collect and transmit 28 days of de-identified work diary records when a practice of concern is identified during enforcement activities - for example, the identification of nose-to-tail schedules. The collection of 28 days of work records allows fatigue experts to assess the risk in the context of a working week, and the frequency of practices within a 28 day period.

New research to measure the impact of specific regulations

There are four research areas where the Alertness CRC has expertise to provide comparative data on the impact of specific regulations:

- field studies using alertness monitoring devices to scientifically compare fatigue and alertness impact of different schedules (e.g. a comparative analysis of nose-to-tail and conventional shifts; and standard hours compared to BFM)
- objective monitoring of sleep during rest periods, to assess the level of sleep drivers are achieving during short and major rest breaks
- data fusion and data modelling undertaken by the Alertness CRC – utilising multiple sources of scheduling and crash data to improve understanding of linkages between different regulatory provisions and alertness levels and;
- developing and testing practical and validated methods to screen and manage sleep disorders amongst heavy vehicle drivers.

Periodic industry surveys

These are to collect large-scale attitudinal and behavioural data regarding driver and operations’ management of fatigue and alertness. Industry surveys are used to quantify the range of operating schedules and practices across the industry so that baseline risk levels can be established.

Alertness CRC

The data framework will be supported by the Alertness Safety and Productivity Cooperative Research Centre (Alertness CRC); a consortium of industry, academics and technology developers. The Alertness CRC aims to develop predictive tools to reduce occupational fatigue, and improve alertness, safety and productivity. The data framework will integrate Alertness CRC research to measure the impact of fatigue regulations.

The longer-term challenge is to develop a simple, repeatable indicator of when a person is too tired to drive safely that can be applied in the workplace or at the roadside. If this can be achieved, the NTC can work with industry and the community to develop a straightforward performance-based law that is simple enough to be easily understood by those who need to comply with the law and those who enforce the law.

Driving heavy vehicle safety through technology: challenges, results and lessons learned at Toll Group: a contextual overview

by Sarah Jones¹

¹ Group Manager Road Transport Compliance, Toll Group

Information based on a symposium presentation facilitated by Sarah Jones at the Australasian Road Safety Conference (ARSC2015), 14 – 16 October, Gold Coast, Australia

Abstract

Toll Group operates nearly 3000 heavy vehicles in Australia. Those vehicles travel around 300 million kilometres delivering 54 million consignments each year. Speed, fatigue and driver inattention/distraction are key policy challenges in the heavy vehicle space. Toll Group has invested in technologies of various kinds to reduce crash and incident risk. This article will explore these technologies – including in the two articles to follow this one - which describe the use of in-vehicle cameras and driver-state sensing machines. It will explore why these technologies were adopted (the problems and risks they were designed to address); how they work; the results they have achieved; and the lessons learned along the way. It will also provide an orientation on the specific context and challenges of heavy vehicle operation in Australia; including the over-representation of heavy vehicles in crashes and on-road incidents and the legal, cultural and enforcement context of heavy vehicle operations.

Introduction

In 1898 delegates gathered at a conference in New York to find a solution to a most pressing problem: how to manage horse-drawn transportation. Horses and horse-drawn vehicles were responsible for 200 road safety fatalities each year. Their emissions were a public health and amenity nightmare, producing between 1.4 and 1.8 million kilograms of manure *every day*. ‘One New York prognosticator of the 1890s concluded that by 1930 the horse droppings would rise to Manhattan’s third story windows. A public health and sanitation crisis of almost unimaginable dimensions loomed’ (Morris, 2007, p. 2).

The conference was intended to run for ten days. It disbanded after three, conceding it had no solution to this seemingly intractable problem. Of course, what the conference organisers did not foresee was the invention of the motor car. A mere fourteen years after the conference ended in disarray, motor cars were more numerous than horses in New York. Somewhat ironically, the car was ‘widely hailed as an environmental saviour’ (Morris, 2007, p. 8).

This story illustrates how new technology can resolve road transport dilemmas and also how that technology generates its own set of challenges. This dialectic between transport problem, technological response and new issue is a recurring theme as this article explores how technology can deliver safety benefits, but also present difficult and contested questions around costs and who should bear them, legal defences, individual privacy, skills, leadership and accountability.

This paper seeks to contextualise and examine the interplay between technology and the heavy vehicle freight industry through a focus on three areas: (1) capacity to invest (2) fairness and competition, and (3) legal defence. The papers that follow are more specific, and speak to technologies used in different areas of Toll Group. They explain the rationale for adopting a technological solution in a given area, the results achieved, challenges faced and the lessons learned to date. This represents the first time Toll has shared the results of its technology journey in such a considered and comprehensive way.

Context: the heavy vehicle industry in Australia today

The road freight task

‘Heavy vehicles’ as defined in the heavy vehicle national law (HVNL) are those vehicles with a gross vehicle mass or gross combination mass of 4.5 tonne and above. These vehicles include rigid trucks, articulated trucks and buses. In 2014 there were 329,464 heavy rigid trucks, 90,904 articulated trucks and 94,131 buses in the Australian motor vehicle census (ABS, 2014).

Australia’s dispersed population and the vast distances between centres make it peculiarly reliant on heavy vehicles. Goods typically travel further and to fewer people relative to other comparable nations, so around 26,000 tonne kilometres of freight is moved annually for every person in Australia (ALC, 2014, p. 3). Between 1971/72 and 2012/13 the total road freight carted in Australia increased from 27 to 203.6 billion tonnes per kilometre (BITRE, 2014, p. 61). This trajectory is expected to continue, with the 2030 national road freight task expected to be 1.8 times its 2008 level (Infrastructure and Transport, 2010, p. 10) and three times the 2006 level by 2050 (Infrastructure Partnerships Australia, 2009, p. 29).

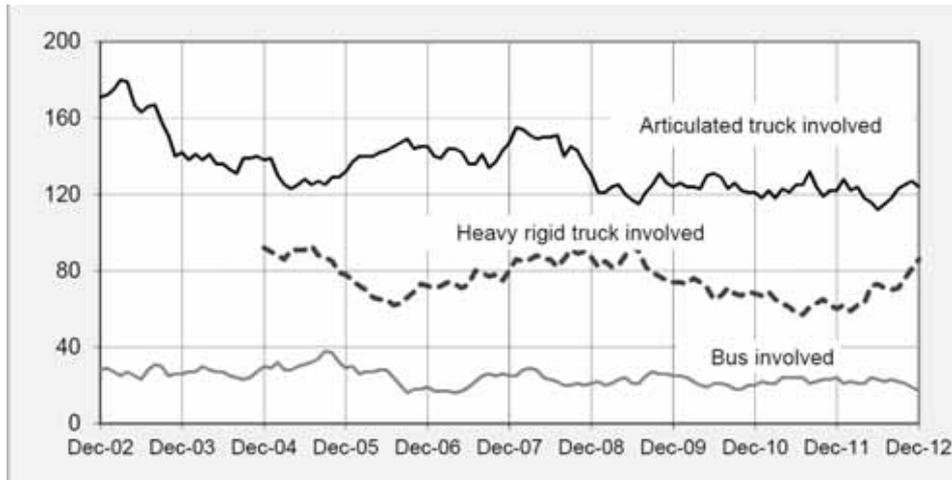


Figure 1. Fatal crashes involving heavy vehicles by type of vehicle (BITRE, 2012)

The contribution of the transport and logistics industry to the Australian economy is significant. The industry was estimated to account for 8.6% of gross domestic product in 2013 and to employ 1.2 million people (ALC, 2014, p. 29).

Safety

The industry's safety record has improved over the years and is generally trending in a positive direction, as illustrated in figure 1.

Data published by National Transport Insurance suggests that when the cost of major crashes is adjusted for net present value 'we could argue that the major crash rate per '000s units has improved by 42.7% since 2003. From a road safety major incident perspective, an unprecedented result' (NTI, 2013, p. 5).

Despite these gains, however, 'each year, heavy vehicles in Australia are involved in around 200 crashes resulting in fatalities, 1500 crashes resulting in hospitalisation, 11,000 crashes resulting in less serious injuries, and 32,000 crashes causing property damage. These events result in death, extensive medical costs, property damage...environmental contamination, and lost productivity (for the affected operator and other individuals) as a result of road blockages and lost time due to injuries, property damage and other factors' (NTC, 2015, p. 52).

Toll Group believes all injuries are preventable and that everyone has the right to go home safely. It is Toll's contention that more can and should be done to reduce the social and economic cost of road-related injury and death, and that technology has a significant role to play in this reduction.

Status of technology in the heavy vehicle industry

At present, innovations in vehicle design are introduced into the fleet through the Australian design rules (ADRs) and Australian vehicle standards regulations (AVSRs). The ADRs and AVSRs mandate the minimum standards acceptable for a vehicle's legal compliance. Manufacturers

can and do feature designs on their vehicles that go well beyond what government currently requires. This means that many heavy vehicle operators are deploying technological innovations to manage both the safety and productivity of their fleets without reference to government. In fact, a 2014 study suggested around 25,000 heavy vehicles (around 5% of the fleet) are already fitted with hardware which satisfies the requirements of the body that certifies telematics for regulatory purposes on government's behalf (Koniditsiosis, 2015).

Systems are readily available that track vehicles and drivers in real time. Governments have generally been reluctant to mandate such systems for industry, one exception being the intelligent access program (IAP) which is compulsory for operators wishing to access higher mass limits routes in NSW. The current Council of Australian Government (COAG) position on telematics and the use of co-operative intelligent transport systems (C-ITS) is that take-up should be voluntary.

Capacity to invest

Toll Group, with its 3,000 heavy vehicles and 25,000 staff in Australia, is a-typical of the heavy vehicle industry. The industry is dominated by small to medium enterprises. Approximately 70% of operators have only one truck, around 24% of operators have between two and four trucks and less than 0.5% of fleets have more than 100 trucks (NTI, undated, p.7). Owner/operators account for around 60% of the industry and around 11% of the profit (NTC, Quinlan and Wright, 2008, p. 11). These smaller operators may have limited resources and consequently limited capacity to invest in new technology. This may be a factor in the over-representation of small to medium enterprises in heavy vehicle incidents (NTI, 2015, p. 6).

The nature of the industry and its capacity restraints naturally influences government policy, including the question of how far and how fast to mandate technology uptake. When new technologies are introduced into the fleet through ADRs, it takes time for those benefits to flow

through. Most operators do not rush out and purchase new vehicles to take advantage of new design features; nor does the law require them to do so.

Consequently, although electronic stability control (ESC) was mandated for new light vehicles from 1 November 2013, it will be 2018 before 50% of the light vehicle fleet is equipped with ESC (BITRE, 2014, p.33). ESC for heavy vehicles is included in the *National Road Safety Action Plan 2015-2017*, but it will take even longer for the technology to flow through the fleet because of the vastly greater costs of new trucks compared to light vehicles. (A standard prime mover costs around \$250,000).

Table 1 below shows the estimated impact on the road toll and economy through currently-available vehicle technologies.

Table 1. Road toll impact through currently available technologies (Hoelzl, 2015)

Technology	Lives saved per year	\$million per year
Autonomous emergency braking system	67	67-187
Lane departure warning system	16	45
Electronic stability control (ESC)	11	31
Fatigue warning system	10	28
Total	104	171-291

There are natural inducements to adopting such technologies, even without government intervention. Many operators value their social license to operate and aspire to be good corporate and community citizens. They value the health and safety of their drivers, and their reputations. Further, they recognise the productivity benefits derivable from reduced rollovers and other incidents. Similarly, many customers are mindful of their reputations and will select carriers on the basis of the safety of their fleet. However, the economic reality of the industry and its dominance by small to medium enterprises limits the capacity to maximally benefit from technology.

It is not simply financial capacity to invest that is an issue, but also community acceptance. High productivity vehicles (HPVs) are ‘next generation’ vehicles designed around performance outcomes rather than to prescriptive rules. This allows designers to innovate and maximise freight productivity while conforming to safety and stability outcomes. These designs need to be approved by a panel convened by the national heavy vehicle regulator (NHVR) and are permitted only on restricted networks.

A comprehensive 2014 Austroads study found that HPVs deliver markedly better safety, environmental and productivity benefits over conventional vehicles. The study found that there were 76% fewer accidents in HPVs than

would be the case for conventional trucks. ‘This will lead to an estimated saving of 96 lives and \$63 million in insurance claims by 2030’ (Austroads, 2014, p. 48).

Despite these benefits, there are pockets of community resistance to HPVs. Other road users can experience HPVs as intimidating, slow and dangerous to overtake because of their size, resulting in terms like ‘monster trucks’. Community concern promotes a conservative access regime, and limits the safety, environmental and productivity benefits possible from utilising the latest designs and innovations.

Fairness and competition

The role and function that technology should play in the heavy vehicle space is contested between government and industry, and within industry itself. There is an ongoing debate about whether telematics should have a regulatory function. In other words: should the data collected by in-vehicle systems be available to government to check that industry is compliant with the rules?

There are sectors within industry that fear the data from compulsory telematics would be used punitively to issue infringements and fines. This fear needs to be seen in the context of the economic and regulatory reality within which industry operates. Competition is fierce and margins can be tight. An average infringement can cost an owner/operator around \$600 – ‘sufficient to nearly wipe out an entire week’s wage’ (NTC, 2013, p. 37). This economic reality, coupled with privacy concerns, explains some of the resistance to compulsory telematics in the industry.

Sectors that might otherwise support compulsory telematics (perhaps in exchange for greater productivity concessions) question whether compliance is reasonably possible in the current regulatory regime. One of the industry’s operational challenges is the sheer breadth of legislation and policy with which it must comply. For a single freight task this could potentially include:

- the heavy vehicle national law
- individual state and territory road traffic law
- dangerous goods legislation
- animal welfare law
- occupational health and safety law
- the road safety remuneration tribunal orders
- the Western Australian fatigue code of practice
- Western Australian CoR laws
- the Federal Interstate Registration Scheme and;
- concessional schemes such as the national heavy vehicle accreditation scheme (NHVAS).

Despite the introduction of the heavy vehicle regulator (NHVR), state-based variations from the national law remain; so vehicle combinations, conditions and loads which are legal in one state are proscribed in others. To further complicate matters, there is no single, comprehensive repository of the rules with which industry must comply on a given route at a given time. This makes it difficult to know with certainty what the law requires. Hence, there is a view within the industry that the greater surveillance and enforcement enabled by telematics is unfair in the absence of a clear and unambiguous picture of what compliance looks like.

A counterargument is that telematics may achieve what other policies have so far failed to do; that is: ensure a level playing field. Investment in safety and compliance costs operators money that must be recouped from consumers and customers through higher prices. What's more, responsible operators do not overload vehicles, run without permits or flout speed and fatigue regulations, leaving them at a competitive disadvantage against operators who do.

Australia's regulatory framework implies, though does not explicitly state, that road transport customers must make their choice of carrier on factors other than price alone. For example, consignors and consignees are required to make 'reasonable inquiries' of the scheduling process to ensure that drivers are not incentivised to speed, drive while impaired by fatigue or otherwise act in ways that might compromise safety. But how many of them do this? And is it policed?

Australia's unique geography makes catching operators who flout the law particularly challenging. It is unrealistic to police our vastly dispersed network using traditional enforcement methods. The corollary of this is fairly low chances of detection and correspondingly low levels of deterrence. A 2013 NTC report found that 'more than 11 billion vehicle tonne kilometres were travelled by heavy vehicles but only 332,214 on-road intercepts occurred' (NTC, 2013, p. 38). Enforcement innovations such as point to point cameras are successfully utilising technology to enforce heavy vehicle safety, but are only deployed on certain routes (Soole, 2011). Mandatory telematics can assist in levelling the playing field and promoting competition based on factors like service and safety rather than price alone.

Supporters of mandatory telematics also point to the fact that a voluntary, rather than mandatory, regime is likely to entrench a 'two-tier' industry: one that invests in technology and whose operating data is transparent to enforcement bodies and, indirectly, customers; and one that operates more traditionally and can 'fly under the radar' of police and regulatory authorities. The debate about electronic work diaries (EWD) is a neat illustration of the dichotomy. Work diaries are a means for drivers to record their work and rest hours to promote compliance with the law. Although electronic work diaries are included in the heavy vehicle national law and are entirely technologically possible, they have no statutory recognition.

One of the reasons for this is that the written work diary (WWD) records time in fifteen minute increments, while EWDs record time precisely. This precision means there's a potential for inequity between the two systems. A driver using an EWD is visible, and potentially infringeable, from the second he/she exceeds allowable hours whereas a driver using a WWD has a fifteen minute window within which to 'hide' and may, in fact, never be pulled over and checked. The debate is currently centred on whether allowing users of EWD an eight minute 'tolerance' would build equity into the system and encourage uptake.

Implementation of EWDs is not expected until 2018, by which point many operators will simply have instituted their own electronic fatigue management systems. After all, an EWD can assist drivers in taking the 'guess work' out of a complex set of fatigue rules and provide advance warning of pending rest breaks. If coupled with advice about available space at upcoming rest bays (as happens on some routes in the United States), this could be a practical and valuable fatigue management tool.

The risk is that by the time the regulatory framework catches up with the operational reality, the gulf will be unbridgeable; or bridgeable only at considerable cost. The photograph below illustrates what can happen when regulatory frameworks are disconnected from industry. This is the interior of a German-registered heavy vehicle. The console includes a digital tachograph to record driving hours, the road pricing black box for Germany, the road pricing black box for Austria and the black box for the European Union: all installed and maintained at operator expense.



Figure 2. Interior of German heavy vehicle (Koniditsiosis, 2015)

Toll Group believes that telematics should be mandatory in the Australian freight industry and that this is the most effective way of taking reasonable steps to meet safety obligations and of ensuring competitive neutrality.

Legal defence

The rapid evolution of technology and its deployment in the freight industry poses a very specific policy quandary for heavy vehicle operators. The heavy vehicle national law incorporates the concept of ‘chain of responsibility’ (CoR) which imposes duties and obligations on all parties in the supply chain to ensure safe on-road outcomes. The law gives parties in the supply chain the benefit of the ‘reasonable steps defence’ which applies where:

You did not know, and could not reasonably have been expected to know, of the contravention concerned; and

either, (1) you took all reasonable steps to prevent the contravention; or (2) there were no steps you could reasonably have been expected to take to prevent the contravention.

The real-time and continuous monitoring capacity made possible by technology creates a perverse disincentive to adopt it from a ‘reasonable steps’ perspective. After all, effective monitoring will identify patterns of non-compliant behaviour on which an operator should act. If the operator doesn’t act and enforcement ensues, it makes it very difficult to argue that one couldn’t ‘reasonably have been expected to know’. Traditional, paper-based systems make for more credible ‘I didn’t, and couldn’t, know’ arguments.

In deciding whether operators have taken reasonable steps to manage their CoR obligations, regulators and enforcers are required to consider the ‘measures available’ and the ‘measures taken’ to manage those risks (S. 620 and 622 of the HVNL). Presumably, if there is a large gap between what is possible to be done and what *has* been done to manage a serious risk, then the prosecution’s case is strengthened.

As noted in Table 1, there are measures available to manage risk through technology. However, they are not mandated and – where they are – there is a ‘grace’ period for adoption. This creates a tension for operators: on the one hand rapid adoption of new technologies narrows the gap between ‘measures available’ and ‘measures taken’ and thereby demonstrates ‘reasonable steps’. On the other hand, the rapid adoption of these technologies can be commercially unviable. Further, if a vehicle is imported with an array of safety features that are not technically required by law (i.e. the ADR/AVSRs) and an operator does not enable or use them, can that operator be said to have taken ‘reasonable steps’? The vehicle may be compliant with design and standards laws, but the operator has elected not to take a ‘measure available’.

The ‘reasonable steps’ implications are likely to loom even larger given the likelihood that the United States will mandate cooperative intelligent transport systems (US DoT, 2014). The US will probably mandate vehicle to vehicle (v2v) C-ITS in 2016, though a start date hasn’t been determined. Cadillac has already announced that its 2017 model will be C-ITS enabled, making it the first manufacturer to incorporate the new technology

into its fleet. If this technology is available on vehicles imported into Australia from the USA, what will this mean for ‘reasonable steps’? A broader question is whether Australian infrastructure and policy frameworks will be mature enough to realise the potential benefits of C-ITS.

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In-truck cameras at Toll NQX

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Information based on a symposium presentation facilitated by Sarah Jones at the Australasian Road Safety Conference (ARSC 2015), 14-16 October, Gold Coast, Australia

Introduction

Toll NQX is a business unit within Toll Group that specialises in long distance road freight solutions for Australia’s northern routes. The operating environment is characterised by remoteness, harsh conditions, limited supporting infrastructure such as rest bays, and longer response times if things go wrong. Long distance, or ‘linehaul’, operations utilise high productivity vehicles such as B-doubles and road trains. It is not unusual for vehicle combinations to weigh up to 130 tonnes and represent a million dollar investment. Typically, vehicles are loaded within Toll NQX depots (of which there are 24) by loading staff, leaving drivers fresh for the task of driving. Unlike pick-up and delivery work which has the inherent stimulus of multiple drop-offs, interaction with customers and urban traffic flows, linehaul driving involves long stretches of one, single task: driving.

It is common for Toll NQX linehaul drivers to clock up 1000 kilometres over a 24-hour period and around 220,000 kilometres in a year. In comparison, Australian motorists drive an average of 15,530 kilometres per year (Roy Morgan, 2013). Professional freight drivers generally do not receive enforcement concessions because of their increased

exposure relative to other (non-professional) drivers. They have the same demerit point thresholds and incur traffic infringements at the same or higher penalty levels than general motorists. (Professional drivers in New South Wales have a higher demerit point threshold than other drivers, RMS, 2015).

Linehaul driving is a solitary task without the myriad of workplace interactions many of us take for granted. This solitariness is often an attraction for linehaul drivers, but it creates unique managerial and safety challenges. For example, how can schedulers judge the fitness for duty of drivers they cannot physically see and assess? How can restorative rest be promoted in remote areas with limited facilities? What is the most effective and efficient response in the event of mechanical failure, rollover or weather event? Such challenges made the risk management opportunities afforded by technology deeply attractive to Toll NQX, and the business unit was an early adopter of GPS-enabled telematics (or “black boxes”) for this reason.

In-truck monitoring for speeding events

Toll NQX introduced in-truck monitoring for speed management purposes in 2001, two years before the

	Moderate speed breach	Major speed breach	Critical speed breach
First offence	Formal verbal counselling to restate company policy	First and final formal written warning stating a further breach will result in termination	Termination of employment
Second offence	First formal written warning issued stating that two (2) further breaches will result in termination	Termination of employment	
Third offence	Final formal written warning stating a further breach will result in termination		
Fourth offence	Termination of employment		

Table 1. Toll Group’s consequence table for speed breaches

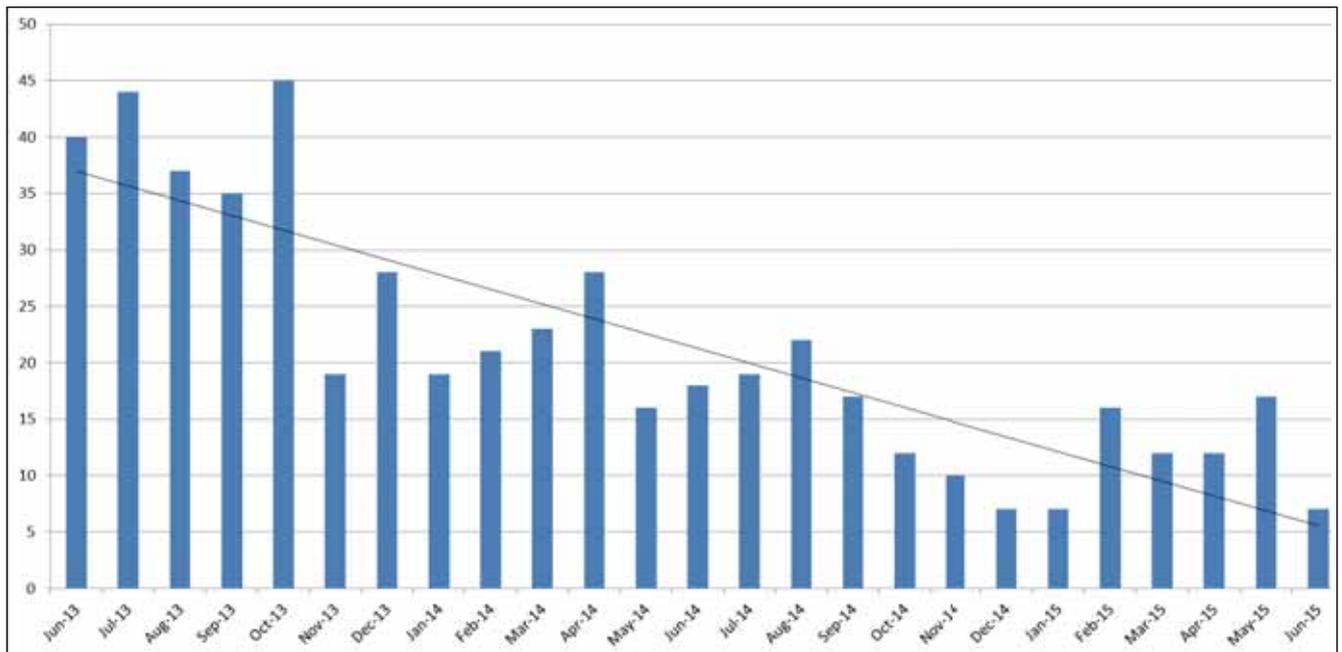


Figure 1. Speed events in Toll NQX from June 2013 to June 2015

landmark *Compliance and Enforcement Bill* which introduced a chain of responsibility approach to speeding. Telematics devices were installed that recorded engine speed data from the engine management system and relayed it to an independent analyst based in Newcastle. This data was used by Toll NQX to identify speeding events and build a profile of riskier routes, conditions and drivers.

In July 2013 Toll Group introduced an Australia-wide speed management standard and in-truck monitoring standard. The standard classifies “speeding events” as any incident at or above 4 kilometres per hour over the vehicle’s regulated speed for three seconds or longer. The telematics device records the total time each speeding incident is sustained at or above 4km/hour by driver and location. Speeding events are classified as either ‘critical’, ‘major’ or ‘moderate’ and result in codified consequences as shown in Table 1.

As indicated in figure 1 above, Toll NQX achieved a significant and sustained reduction in speed events between June 2013 and June 2015.

The vast majority (99%) of the speeding events shown in Figure 1 were for moderate speed breaches, which are incidents where the breach was less than 10km/hour over the speed limit. As such they resulted in verbal counselling of drivers, which was an opportunity to coach the driver in behavioural change and to reiterate the importance of the Toll values, including that no job is so important that it cannot be done safely. In an industry that has sometimes prioritised productivity (“getting the job done”) over safety, this is an important cultural shift. Toll NQX has further driven this cultural change by instituting a business unit policy that B-doubles be speed-limited to 95 km per hour.

Despite the safety benefits yielded by speed monitoring, Toll NQX was frustrated by the limitations of the telematics data. The data indicated speed, location and time but shed no light on the surrounding circumstances. It revealed the ‘what’ but not the ‘why’ or the ‘how’. This often made it difficult to establish an objective root-cause understanding of an incident. For example, a speeding incident above 100km/hour might suggest a defective speed limiter. But speed limiters (which are mandated for heavy vehicles) do not work effectively on steep downhill runs. Telematics data could reveal nothing about factors such as road condition and topography that would point to a downhill gradient sufficient to ‘over-ride’ a speed limiter. Similarly, telematics data could not provide Toll NQX with crucial information such as traffic conditions, signage, animal interaction, weather events, driver state (such as fatigue and distraction) or the behaviour of other road users: all of which can influence speeding.

Further impetus for an approach that went beyond telematics data was provided by the introduction of the heavy vehicle national law (HVNL) in all states except Western Australia and the Northern Territory from February 2014. The ‘reasonable steps’ component of the HVNL requires that incidents and near-misses be approached as learning opportunities and catalysts for change. Identifying and remedying past compliance problems is a matter that courts may consider in deciding whether reasonable steps have been taken (HVNL section 622 (1j)). An analytical and proactive approach to compliance issues can therefore establish a reasonable steps defence in the event that an on-road incident occurs. Such a defence can be important in protecting the reputation of both the organisation and the driver.

In-vehicle cameras

Recognising the limitations of telematics data and mindful of how reasonable steps was likely to be constructed in the HVNL, Toll NQX began introducing in-vehicle cameras in trucks in 2011. The introduction followed a year of research and investigation into the capability of the technology and its implications for drivers. Toll NQX selected a product called 'DriveCam' which records both in-cab and external footage. The footage is both visual - capturing the driver and the road ahead - and audio within the vehicle cabin.

Challenges

The obvious challenge facing Toll NQX was how to introduce camera technology in a way that was least intrusive for drivers and protected privacy but still enabled the root-cause analysis that GPS telematics couldn't provide. One of the attractions of DriveCam from Toll NQX's perspective is that it continually records and then deletes data, except in the case of a 'G force event' or when activated by the driver. G-force events include sudden braking, harsh cornering, and the 'bounce' produced by uneven road surfaces or swerving. Where a G-force event occurs DriveCam records 12 seconds of vision and audio: the eight seconds leading up to the event and the four seconds afterwards. Drivers can also elect to record data by pressing a button in the cab.

An additional layer of privacy protection is provided by the fact that the recorded data is analysed by a third party based in California in the United States. This third party analyses the footage and emails data that may warrant further investigation to a limited number of specially trained Toll NQX staff. These staff are bound by a code of conduct that stipulates the conditions under which they may view footage (for example, no one else may be in the room when it is viewed) and what they may do with it.

Drivers had concerns that the footage would be used primarily as a disciplinary tool to performance manage and even sack drivers. An extensive dialogue between management and staff emphasised that the footage would be used as an educative and coaching rather than a punitive tool. Toll NQX drivers' experience with the speed management policy provided a useful precedent in this regard. The dialogue also emphasised the value of the footage in objectively assessing why incidents occurred and providing drivers with a defence. This latter point is very important. Where an on-road incident occurs, there is often an assumption that the heavy vehicle driver is likely at fault. Camera footage provides a means of establishing liability more clearly and objectively than the recollection of the parties involved. The power to activate the system where an incident or near miss is imminent was highly attractive to drivers. Take-up of the system was further incentivised by deploying the DriveCam system in the newest vehicles. As the prospect of driving the 'latest and greatest' trucks is highly attractive to many drivers, this provided positive reinforcement for the DriveCam system.

Following the consultation period, most drivers readily adopted DriveCam. There were instances of drivers attempting to obstruct the camera's view with towels, resulting in disciplinary action. Such incidents now occur only rarely and almost invariably with new drivers. The only jurisdiction in which the technology posed an industrial issue was in Victoria, where the Transport Workers' Union argued against the technology in a case before the FairWork Commission. The Commission found in Toll Group's favour, noting that 'the evidence indicates the system can contribute to better safety outcomes in the road transport industry and should be considered by the parties in this context' (FairWork Commission, 2014, p. 15).

Results

To date, more than 140 Toll NQX prime movers have been fitted with the DriveCam system. Each camera costs around \$1000 to install and \$90 a month to monitor. Toll NQX is therefore outlaying \$151,200 in monitoring fees each year and has incurred \$140,000 in non-recurrent capital costs. Additional indirect costs are incurred through the need for Toll NQX personnel to review the footage. This is estimated at around \$40 per unit, per month, representing an annual spend of \$67, 200 (Toll, 2013).

Around 3,700 video clips are on forwarded to Toll NQX from the third party provider each month. The vast majority of these clips (about 94%) require no further follow-up. Typically these are incidents where the camera has been triggered by the truck travelling over a pot-hole (although ironically there have been instances where trailers at the back of a combination have rolled and the system has not registered a g-force event). As indicated in Figure 2 below, the motor vehicle incident (MVI) rate has trended downwards since in-truck cameras were introduced in 2011. A motor vehicle incident is defined as 'an incident involving a registered vehicle carrying out work for Toll, resulting in damage to the vehicle and/or third party vehicle/property'. The radical reduction between December 2010 and December 2011 should be interpreted with caution as this period coincided with changes to how data was inputted into the system. However, the data shows a near halving of MVI frequency rates between December 2011 and April 2015 when the methodology remained consistent.

The video footage has proven invaluable as a learning and remediation tool. In instances where the Toll NQX driver's behaviour has led or contributed to an incident, the objective nature of the footage has helped defuse what might otherwise have been a difficult and contested intervention. Driver managers report that the footage sometimes shocks drivers, who have a different or partial recollection of what occurred. Toll NQX's company doctors speculate that this partial recollection occurs because the drivers experience a high cognitive load during an incident. Their focus is on managing the incident, which seems to impact recollection. The camera footage enables the incident to be dissected and analysed with minimal emotiveness. This makes it a powerful learning tool. As

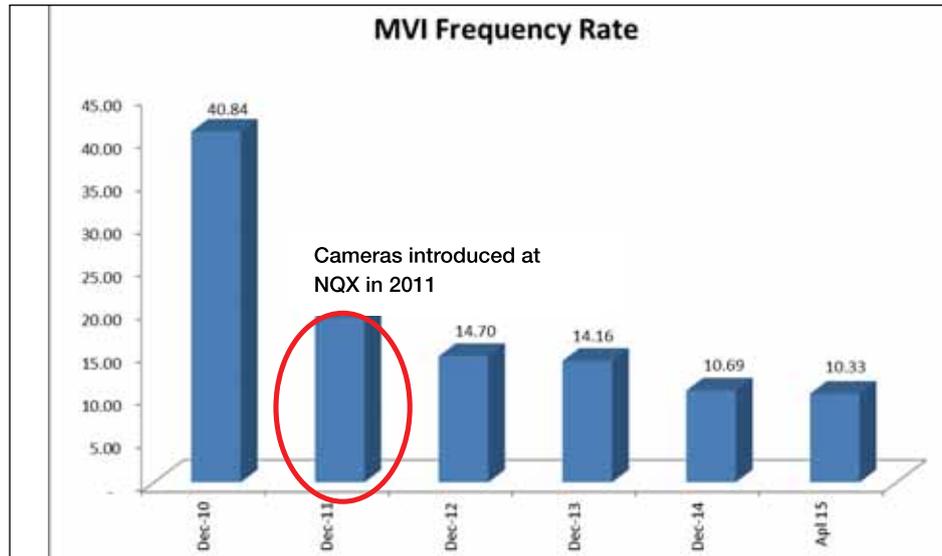


Figure 2. Motor vehicle incident (MVI) frequency rates at Toll NQX December 2010 to April 2015

a result ‘managers are building meaningful relationships with drivers that centre on honest discussions about their behaviour, their health, their lifestyle and the risk environment’ (King, 2014). No driver has been dismissed purely as a result of camera footage. Instead, camera footage tends to support observations of driver behaviour garnered through other channels.

Among the driver habits and behaviours that camera footage has highlighted is the use of seatbelts. The seatbelts in Toll NQX vehicles are high-visibility, so it is apparent in the camera footage if seatbelts are not being worn. Consistent with the findings of Mooren, the Federal Motor Carrier Safety Administration and others, Toll NQX grapples with a cohort of drivers that do not consistently wear their seatbelts (Mooren, 2012, FMCSA, 2015). The camera footage is helping to counter this. There have also been instances of heavy vehicle drivers following other vehicles too closely or cornering too fast. Both behaviours have seen noticeable improvements since DriveCam was introduced.

In instances where an incident has been largely or entirely triggered by circumstances outside of the driver’s control, the footage is helping to establish liability and drive down investigation time and cost and insurance premiums. Toll NQX estimates the cost saving produced by in-truck camera footage to be around \$15,000 per investigation (Toll, 2013). A review of motor vehicle insurance claims data for Toll NQX between July 2010 and June 2013 indicates that the average monthly number of claims reduced by a factor of around 2.5 following the introduction of cameras. This equates to an average monthly reduction in insurance claims costs of around \$25,000 (Toll, 2013).

Not only has the footage driven costs down, it has also helped to shore up driver pride. The footage reveals instances of dangerous driving by other road users which has exonerated Toll NQX drivers internally and, in some instances, with external enforcement agencies. The

competence and professionalism of drivers was noted by the FairWork Commission which, having viewed some of the footage, stated that the cameras ‘provided some significant examples of the skill and quick thinking of drivers, enabling them to avoid what would otherwise have been the disastrous consequences of the seemingly unlawful and negligent actions of other road users’ (FairWork Commission, 2014, p. 4). A future application of some for the footage may be to advise and inform regulatory bodies on ‘share the road’ campaigns.

One of the most surprising findings from the data is the extent to which driver distraction contributes to G-force events. The camera footage has revealed how apparently small actions can divert drivers’ attention. These actions include inserting CDs, changing radio stations, using mobile phones and reaching for food and drink. In one instance, a rollover occurred on the Bruce Highway north of Brisbane when a driver reached into the fridge for his lunch. The fridge was located to the driver’s left immediately adjacent to the driver’s seat. Fortunately, the driver was not hurt in the rollover and there were no impacts for other road users. However, the cost incurred in repairing the vehicle, damaged freight and customer annoyance was considerable. That footage led Toll NQX to reconsider how cabin design and layout may inadvertently encourage driver distraction.

Consequently, Toll NQX has worked with truck and parts manufacturers to redesign cabin features. For example, many vehicles now feature dash-fitted phones that are set to auto answer, the radio can be controlled from the steering wheel and the fridge is now locked when the vehicle is moving so the driver cannot reach around and open it. Toll NQX went on to participate in a study commissioned by Toll Group on how truck cabin design and onboard systems might impact safety (Young and Lenné, 2014). Toll NQX also made the topic of distraction a feature of its toolboxing sessions and communications with drivers.

Lessons learned

Toll NQX's experience demonstrates the role that technology can play as an enabler of behavioural change. The key point here is that technology and data, by themselves, do not change behaviours. If the in-truck cameras had been introduced with less consultation, without privacy management and in a context that was punitive rather than remedial they would not have delivered safety results. The safety benefits emerged because the footage was used to educate and coach drivers and gave drivers some agency in when the system was activated. Further, both drivers and Toll NQX management benefited from a more efficient and objective means of establishing liability in the event of an incident.

In a broader policy and regulatory sense, Toll NQX's experience has challenged the conventional wisdom that speed and fatigue constitute the primary heavy vehicle

driving risks. Heavy vehicle driver distraction has not received the same attention as speed and fatigue. For example, the accident causes analysed in one of the most credible and useful heavy vehicle accident data sources – the National Truck Accident Research Centre – include inappropriate speed and fatigue but not driver distraction (though it is conceivable that driver distraction is captured in one of the other reported categories). Where driver distraction is discussed as an on-road risk, such as in the *National Road Safety Strategy 2011-2020*, it is in a general rather than heavy vehicle-specific context.

Perhaps part of the reason for the comparative policy neglect of driver distraction in the heavy vehicle context is that it is not recognised within the chain of responsibility (CoR). CoR recognises that the actions and inactions of parties in the supply chain can affect and influence driver fatigue and speeding and the mass, dimension and load restraint of the vehicle. These five factors (speed, fatigue, mass, dimension and load restraint) are all represented



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in the heavy vehicle national law and all have extended liability offences attached to them. It is less clear how a party in the chain might influence driver distraction. The ways in which supply chain parties could prompt driver distraction – for example by phoning drivers to check on their whereabouts and estimated arrival time – are fairly easily managed by not disclosing driver contact details.

Further, it may be that distraction is assumed to be a *symptom* of driver fatigue, rather than a distinct behavioural category in its own right. But it may also be possible that distraction, as a form of stimulation, could counter fatigue. For example, anecdotal evidence suggests that interacting with other drivers on the CB radio is sometimes used by drivers to revive themselves. Toll NQX welcomes further policy investigation of the role of driver distraction in the heavy vehicle policy context.

Into the future, in-truck cameras could be adapted to play a role in mass, distance, location charging; if indeed that is the charging option pursued by government. Cameras could conceivably be configured to record not just the driver in-cab and the stretch of road immediately in front of the windscreen, but the road beneath the vehicle. Coupled with vehicle suspension data this footage could be relayed to the appropriate road funding agency to prompt road resurfacing or other mitigation. In the absence of an infrastructure response, road condition could be used as a factor in variable registration costs (harsher conditions cause greater wear and tear on vehicles and therefore impact productivity due to extra servicing requirements). Toll NQX will continue to explore the possibilities of in-truck cameras and share its experiences with policy makers.

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Driver State Sensing (DSS) machines at Toll Resources and Government Logistics

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Information based on a symposium presentation facilitated by Sarah Jones at the Australasian Road Safety Conference (ARSC 2015), 14-16 October, Gold Coast, Australia

Introduction

Toll Resources and Government Logistics (TRGL) is a business unit within Toll Group that specialises in logistics services to the oil and gas, mining, and government and defence sectors in Australia, Asia and Africa. It is a diverse and often high-risk enterprise that transports dangerous goods on public roads and on private roads owned and/or managed by mine sites. Goods carted include fuel, security sensitive ammonium nitrate, coal, iron ore, class 1 explosives, zinc and lead. Unsurprisingly, given the nature of the goods carted, TRGL operates in a highly regulated environment. A plethora of laws and regulations can apply

to a single transport task, including the heavy vehicle national law, dangerous goods legislation, workplace health and safety laws and mining-specific legislation such as the Mining and Quarrying Safety and Health Act and the Coal Mining Safety and Health Act.

The incident at Mona Vale in New South Wales in 2013 illustrates the salutary importance of risk management in dangerous goods cartage. That incident left two people dead and five injured, caused a 60% reduction in the share price on the Australian Stock Exchange for the company concerned (McAleese Transport), cost 540 people their jobs and led to more than 300 vehicles in the fleet being

grounded (Hassall, 2014). It was as a direct result of this incident that Australian Transport Ministers instigated the roadworthiness projects currently being managed by the National Transport Commission (NTC) and the National Heavy Vehicle Regulator (NHVR) (NTC, 2014).

What is perhaps less commonly known is the extent to which mindfulness of risk motivates dangerous goods customers to demand change and innovation from their carriers as a condition of work. This is chain of responsibility in action: customers using their influence to drive safety and compliance. For example, it is standard for fuel suppliers such as Shell to stipulate a maximum age for vehicles carting their goods, thus ensuring that the fleet is equipped with the most modern designs, standards and technologies. This paper discusses how customer concerns influenced TRGL to explore technological solutions to fatigue management. Although the system TRGL deployed also has a distraction management function, this paper addresses only fatigue management.

Managing fatigue

The risk posed by fatigued drivers is well understood in the road safety literature and is reflected in laws applying to heavy vehicles. Fatigue is estimated to be the predominant cause of 12% of serious injury crashes involving heavy vehicles (NTI, 2013). Not sleeping for more than seventeen hours can have effects on the human body similar to a blood alcohol concentration of 0.05. Not sleeping for more than twenty four hours can have effects on the human body similar to a blood alcohol concentration of 0.10 (Williamson, Feyer, Friswell and Finlay-Brown, 2000). The literature suggests that commercial vehicle drivers sleep, on average five to 6.5 hours per night – well below the recommended eight hours (Sharwood, Elkington, Stevenson and Wong, 2011, p. 25). Further, commercial vehicle drivers would appear to have a higher prevalence of sleep apnoea than the general population and ‘it may be expected that the crash risk is greater in a CMV [commercial motor vehicle-driver] population [although] this has not been empirically demonstrated’ (Sharwood, Elkington, Stevenson and Wong, 2011, p.25).

Managing fatigue is therefore vital for safe driving. There are essentially two components to fatigue management from a legal and compliance perspective: prescribed work and rest hours, and fitness to drive. The first component is relatively easily managed. TRGL uses the technologies Trimble and MT Data in some parts of the business to monitor work and rest hours in real time. It can therefore respond promptly in a situation where a driver is at risk of exceeding allowable work hours. National work diaries are also audited retrospectively to ensure compliance with the heavy vehicle national law.

‘Fitness for duty’ is a much more difficult proposition. A driver could be compliant with all work and rest hour regulations but still be impaired by fatigue. However, because there is no objective test for fatigue (such as there is for blood alcohol concentration), recognising and managing fatigue is not an exact science. It is further

complicated by the fact that ‘fatigued people are unaware that they are not functioning as well or as safely as they would if they were not fatigued’ (NTC, 2007). For this reason, standards and processes are required to supplement, and even veto, the drivers’ judgement about their fitness.

In 2011 TRGL’s mining services business faced a serious dilemma. One of its contracts was at risk because of two vehicle rollovers in quick succession. Fortunately, no one was hurt in the rollovers, but the risk was unacceptable. Fatigue was suspected in both cases and TRGL set about investigating how or if technology might assist in managing the risk.

Driver state sensing (DSS) pilot program at German Creek

In July 2011 TRGL began a trial of ‘driver state sensing’ (DSS) machines designed by the company Seeing Machines at its German Creek operation in Queensland. At the time Toll utilised twenty heavy vehicles to haul coal from production sites to the wash plant. The vehicles worked in twelve hour shifts, one shift being from 6am to 6pm and the other from 6pm to 6am. DSS machines are in-vehicle systems that capture eye-lid and head motion through sensitive cameras mounted at eye-level in the vehicle. The fact that the driver is not required to wear or affix equipment, such as glasses, was a key factor in selecting this technology for trial. Figure 1 below illustrates the portion of the driver’s face that the initial DSS prototype captured:



Figure 1. Footage capture by DSS version 1

The DSS works on the premise that a micro-sleep is a symptom of fatigue detectable by the camera. The obvious danger of a micro-sleep is that a vehicle may travel a considerable distance with a driver in a semi-conscious state and therefore not in full control of the vehicle. Table 1 below illustrates how far a heavy vehicle can travel at various speeds in a two second period:

Travel Speed	Distraction Time	Distance Travelled (metres)
40 km/h	2 seconds	22.22
50 km/h	2 seconds	27.78
60 km/h	2 seconds	33.33
80 km/h	2 seconds	44.44
100 km/h	2 seconds	55.56

Table 1. Distance travelled in two seconds at various speeds



Figure 2. Components of Driver State Sensing (DSS) system

How the DSS system works

There are three components to the driver state sensing system: (1) in-cab mitigation, (2) real-time intervention and (3) post-event reduction. In-cab mitigation occurs when the system detects what might be a ‘fatigue event’, defined as an eye closure of 1.5 seconds or more while the vehicle is travelling over 5km/hour. The fatigue event triggers an aural alarm and vibrations in the seat.

At the same time, video footage of the incident is captured and relayed to a monitoring team. The team review the footage and ‘weed out’ false positives, i.e. footage that is not indicative of fatigue. For example, the camera sometimes interprets the glare from spectacles, reflection interference from a high-vis vest and even designs on eye-wear as ‘pupils’. The camera may also interpret glances to the left and right as the driver checks for oncoming vehicles as fatigue events if the glance is sustained for more than 1.5 seconds.

Where the footage is determined to be a genuine fatigue event, it is categorised as follows:

- **Fatigue mitigation:** occurs when the eyes are closed in a controlled manner, for example to rest the eyes
- **Drowsiness:** occurs when the driver appears to have some awareness of his/her fatigue and is visibly fighting it, for example by resisting eye closure and;
- **Microsleep:** which occurs when the driver’s eyelids close involuntarily, often accompanied by an eye or head roll.

Once categorised, site supervisors are alerted to the fatigue event by the monitoring team. The supervisor will respond according to the fatigue management plan for the site. The response might include a discussion with the driver about his/her current state and fitness to drive. As a result of the discussion the driver may self-select out of the shift or the supervisor may make that determination. Alternatively, the driver may elect to take a rest break. The footage is also reviewed by TRGL’s compliance manager who has the authority to halt the vehicle and remove a driver from shift if he has concerns about fitness for duty. In all instances across all TRGL sites where three fatigue events occur in a single shift, the driver is stood down for the remainder of the shift, regardless of the driver’s personal assessment of their fatigue risk.

The third component of the system involves post-event follow-up whereby the monitoring team contact the site supervisor to ensure that intervention occurred and to discuss mitigations enacted. The monitoring team also collate and analyse the data produced by the system to determine trends and issues. This data is then shared with TRGL management and with the system providers to inform ongoing refinement of the technology and the supporting policy. Figure two below illustrates the components of the DSS system.

Results

When the initial DSS pilot was run at German Creek, baseline data was collected to provide a point of comparison for fatigue events pre and post implementation. In the first phase of the pilot, the cameras were enabled but no other action taken. So, if a fatigue event was detected it

was recorded but the driver and supervisor were not alerted and no follow-up action was taken. In the second phase, the in-cab alerts were enabled and the fatigue management plan initiated.

As indicated by Figure 3 below, fatigue events fell by 82% when the system was fully initiated.

This data needs to be interpreted with extreme caution. It is certainly not the case that the reduction in fatigue events represents a commensurate reduction in actual fatigue. Part of the reason the fatigue events fell so radically was that once the complete system was activated the monitoring team filtered out false positives. The baseline data includes everything that the camera *interpreted* as a fatigue event; the post-implementation data has the benefit of human judgement about whether the footage was likely to reflect *actual* fatigue.

At the same time as the DSS system was enabled, TRGL ramped-up its efforts to educate drivers about the risks of driving while impaired by fatigue. The business featured more information about health and wellbeing (including the importance of diet, exercise and sleep) in its toolboxing sessions. It is therefore difficult to disaggregate exactly what proportion of the reduction in fatigue events is attributable to the DSS system and what to lifestyle changes instigated by drivers as a result of these sessions and other information. In retrospect, it would have been useful to survey drivers on their perceived levels of fatigue (using an instrument such as the Epworth scale) and perceived importance of managing fatigue pre and post implementation.

Despite these methodological limitations, TRGL was confident that the pilot (which incurred capital costs of around \$270,000) was having a positive impact on fatigue management and elected to continue and extend its use. To date 188 vehicles have been DSS-enabled within the TRGL business unit. Ongoing refinement of the technology and volume-based purchasing has resulted in a significant price reduction. TRGL incurred additional costs from late 2013 when it assumed the monitoring function from Seeing Machines and initiated 24/7 monitoring from its Brisbane.

Perhaps the most significant result achieved to date is that no operational TRGL vehicle equipped with DSS has experienced a rollover. TRGL is therefore confident that there is a correlation between its deployment of the DSS system and the elimination of rollovers. At the same time, Toll Group has intensified its efforts to eliminate rollovers across the entire business through adopting a zero target. Toolboxing, training and information bulletins are utilised to keep awareness of the risk of rollovers high. Again, this makes it difficult to disaggregate the impact of the DSS system from other initiatives and to attribute causal relationships.

Challenges

Technology cannot yet (and may never) provide an objective measure of fatigue in the way that a breathalyser can determine blood alcohol content or a speed camera can detect vehicle speed. Systems like DSS provide evidence of human behaviours that *might* indicate driver fatigue. The system has been progressively refined over the four years

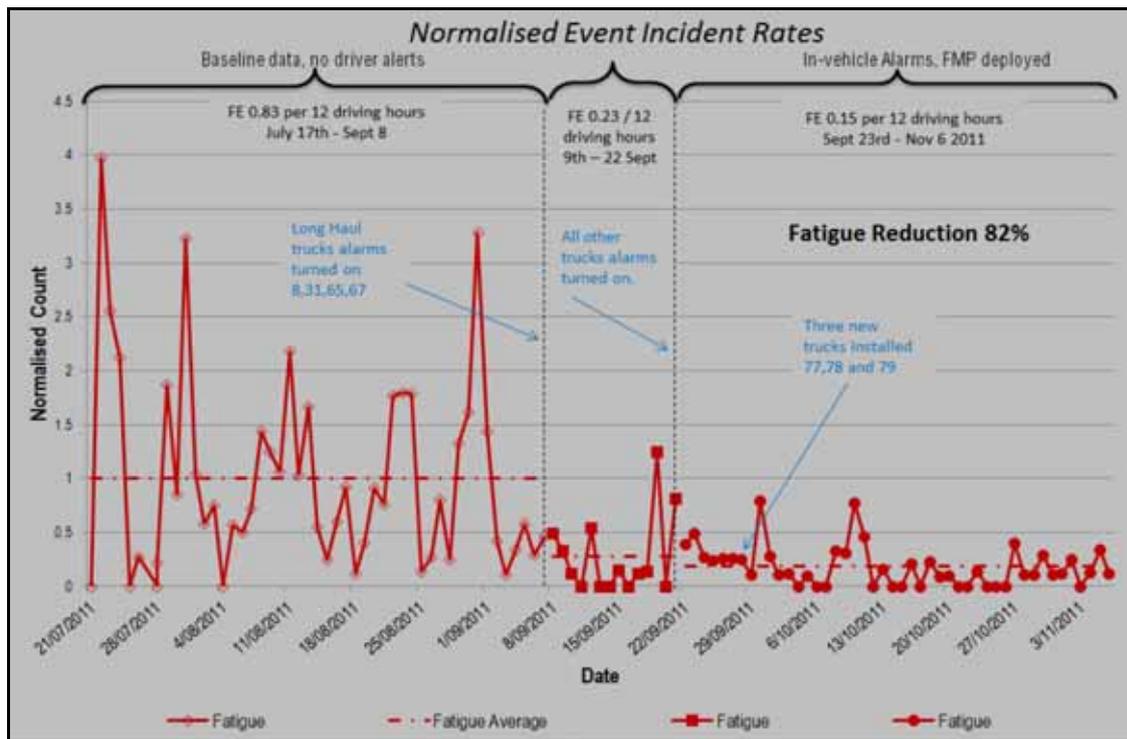


Figure 3. Fatigue events at German Creek July 2011 to September 2011

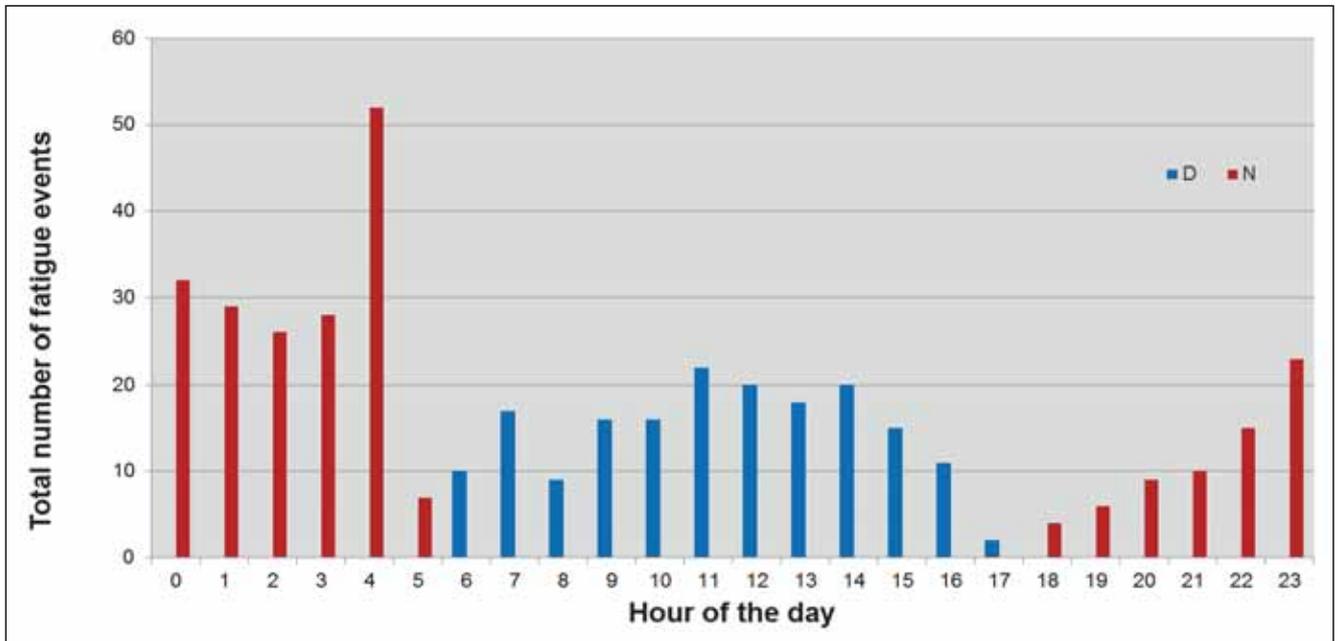


Figure 4. Fatigue events by time of day (24 hour clock)

since the initial pilot and is now significantly more accurate at detecting true positives. Rather than capturing only the eyes, the system now captures the entire face through 75 ‘mapping’ points. It has become smarter at recognising an individual’s baseline ‘normal’ and is more likely to detect genuine fatigue events as confirmed by the monitoring team. However, false positives remain, all of which trigger the alert within the vehicle even though no subsequent follow-up occurs.

The alert can be jarring and unpleasant for drivers. Of course, in genuine fatigue events this produces the intended result: it shocks the driver into a state of wakefulness. The TRGL compliance manager has viewed footage of a driver awakened by the system mere seconds before the vehicle was about to drive off a cliff. It is his subjective assessment, therefore, that the system saves lives. However, when the system is engaged because of false positives it can promote anxiety in drivers; a state best described as being ‘on edge’. On occasion, drivers have been reduced to tears by the stress and discomfort caused by the alerts. The emotional and psychological impact of the alerts is under-researched and, at this point, poorly understood.

As noted, TRGL instituted a ‘three strikes’ rule for fatigue events. However, on occasion the risk posed by the first fatigue event is so high that the driver may be directed to stand down or take immediate rest. Such a decision has commercial repercussions: leaving a vehicle idle for one hour costs Toll and the site up to \$27,000 and can compromise production targets. TRGL recognised that the commercial imperative might prompt managers to err on the side of cost rather than caution. Consequently, decision making authority on the risk posed by first and second fatigue events was vested in the compliance manager, rather than the site managers. This helped to mitigate the risk of prioritising production over safety considerations.

One of the challenges from an analytical perspective is that the system is configured to the truck rather than the driver. This means that fatigue reports are captured by vehicle and by shift. An additional administrative step is required to match that data to a driver as there may be more than one driver per shift. At this stage, TRGL has not had the resources to analyse the data at the driver level. The data that has been aggregated at the vehicle level suggests that drivers are at most risk of fatigue events between midnight and 6am with a pronounced peak at 4am, as illustrated in figure 4 below.

Lessons learned

TRGL’s experience in using technology as a risk management tool for fatigue illustrates that technology is an enabler, not a panacea. In and of itself technology does not solve the fatigue problem. After all, the technology does not and cannot directly challenge the ideas about work, productivity and well-being that the driver cohort may hold. These ideas might include that it is ‘unmanly’ to admit to not being fit for duty or to acknowledge that there are personal or health problems that may be compromising restorative rest. Drivers sometimes identify with others who share their route or shift and may fear that they are ‘letting the side down’ if a vehicle is unproductive on their watch.

Such ideas can only be combatted through training, conversation, information, modelling the appropriate behaviours and trust. Cultural change is often slow and difficult, and it is important to bear in mind that until the 1980’s safety was considered ‘a peripheral concern’ in the trucking industry (NTC, 2013, p.20). Technology supports cultural change by keeping health and safety issues such as fatigue management highly visible. It provides management with the data to report and track safety-related key performance indicators. As noted by Smith and Jones,

the video footage is also a powerful training tool, providing drivers with objective evidence of problematic behaviours and a catalyst for change (Smith, Jones, 2015).

Introducing technology and leveraging from it effectively also requires a wholesale rethink about the skills and attributes needed in the heavy vehicle freight industry. Traditionally, the core competencies of a good trucking company were putting the right loads with appropriate restraints on the right vehicles and the right roads. Now, however, TRGL requires expertise in data monitoring and analysis, in coaching and mentoring drivers, in the promotion of health and wellbeing and even in psychological counselling. Technology will only deliver benefits where there is recognition of, and resourcing for, the new skills needed to profit from it. Trucking can no longer be construed as a ‘blue collar’ industry.

TRGL’s experience also suggests the importance of forging a genuine, long-term partnership with an IT provider. Seeing Machines has shown a willingness to engage with and understand the specific needs and requirements of trucking in a mine-site environment. They have customised the system to reflect the operational reality. As the technology has improved and progressively eliminated false positives and design issues, TRGL has become an advocate for the technology. The relationship between technology provider and end user is therefore mutually beneficial.

Ultimately, the technology requires a human being to make a judgement call about whether a driver may safely continue to work. The system provides managers with better information than they would otherwise have, but leadership and accountability have to be in play for the system to work. All the data in the world means nothing without the authority and empowerment to say ‘you are not fit to drive’ as a result of it.

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Road safety: a reliable investment for every profitable heavy vehicle business

by Jerome Carslake

Manager, National Road Safety Partnership Program (NRSPP)

Introduction

The majority of Australians take the road transport system for granted; few appreciating what lies behind moving people and goods seamlessly from A to B. The nation’s productivity relies on a safe and efficient transport system.

It is the economy’s life blood as well as the glue of our social fabric. However, the downside is serious injury and death which we must seek to eliminate. The only time transport comes into focus for the community is when something negative occurs and the lives of “Joe Public” are touched.

As the manager of the National Road Safety Partnership Program (NRSPP) I am privileged to interact with leading organisations where road safety is a core pillar in their daily operations. Almost all organisations – public and private – depend to some degree on safe and efficient road transport, thus Partners in the program come from all sectors, sizes and modes.

One sector strongly engaged in the NRSPP is the freight vehicle sector. These Partners are very active, keen to share their knowledge and raise awareness of just how hard they are working to improve road safety; and investing in their drivers and fleets to protect other road users.

This opinion piece presents my thoughts relating to road safety issues within the heavy vehicle sector observed since the NRSP was launched in May 2014. They stem from interactions with big and small operators across a range of operations - all of which prioritise road safety.

Does the community understand the realities of interacting with heavy vehicles?

Sadly, heavy vehicles are over represented in Australia’s road crash fatalities, accounting for nearly 18% of the nation’s road deaths per annum while representing 3% of the total vehicle fleet. This is mainly due to the sheer mass of heavy vehicles guaranteeing the truck will “come off best”: put simply the bigger the vehicle the larger the mess.

Further, many people, particularly in the city, simply don’t like trucks, especially big ones. Some fear interacting with them and fail to understand the realities of how to safely interact with trucks. Yet the majority of heavy vehicle crashes are single vehicle incidents. However, for collisions involving other vehicles and fatalities, the truck was not at fault 84% of the time.

Road users simply do not understand the basics, for example, that a truck leaves so much room between the vehicle ahead of it in order to provide sufficient braking distance, not to provide merging options for other vehicles.

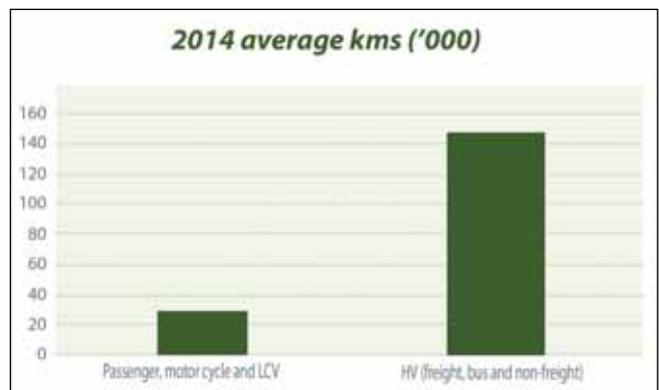
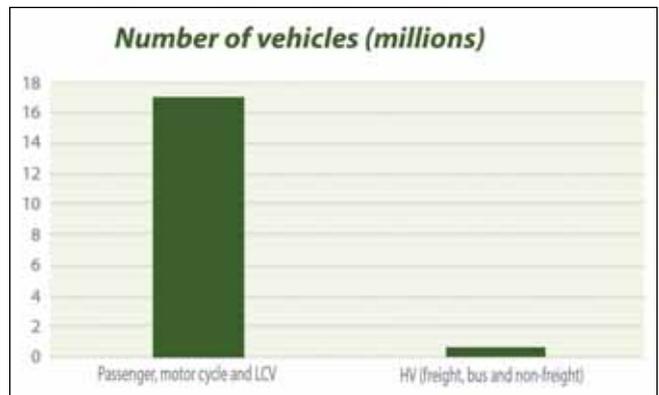
Community fear and misconception of trucks is often reinforced by the media. Images of the carnage of car-truck crashes are horrific and “demand” media coverage but at a time when investigations of causes are in their infancy, incorrect conclusions of fault are often drawn with the initial headline ‘truck kills motorist’.

The involvement of a heavy vehicle in a crash is not causation and the personal impact on truck drivers is rarely covered. They have to live with incident; they question their actions and revisit the issue in their minds. For many this is the end of the line and they decide to find a new career.

One business outlined to me a concern it has in urban area when their heavy vehicles come to a stop at a red light. Their drivers have to remain alert and focused on their mirrors watching what pedestrians may do to cross the road as fast and directly as possible. To save time, some pedestrians sometimes choose to jump over the hitch between the truck and trailer as a short cut. One recent story even included a couple passing a pram over. The organisation worries about the public perception should such a short cut become a pedestrian’s death.

Road users need to realise they all have a responsibility in reducing their own risk. The road network is a shared environment with light, heavy and vulnerable users all interacting. The focus of road users must be sharing the road; a major step forward is simply being courteous and careful.

Such an approach will help heavy vehicle operators. The community must realise a truck is a business asset which generates revenue and when it’s not working it becomes a cost. As a result, they cover significantly large distances when compared to a light vehicle and therefore each heavy vehicle is at greater risk of being involved in an incident than other users as illustrated below.



Road safety should be the central pillar throughout the supply chain

Hiring good drivers is increasingly difficult - the average age of truck drivers is now 57 and therefore the sector cannot afford to lose good drivers. Freight companies are under immense pressure, both regulatory and competitive, due to very tight margins.

As in all competitive market places businesses take different approaches, which bring the best and worst of players through the supply chain. There are those companies who sadly do not meet the standard; and their actions put the sector at risk and increase pressure for further regulation.

Undoubtedly the issue though is proactive road safety comes at an upfront cost. Being safe requires investment but it provides long term returns and often ensures the business is operating in a truly sustainable mode.

Businesses prioritising road safety make a conscious decision that their drivers, the public and corporate responsibility comes first and understand that sustainable profits follow. It is false economy to squeeze costs from the

supply chain by viewing road safety as an unnecessary cost because other supply chain costs increase, such as reduced reliability, damaged goods, public image, overall service and compliance breaches.

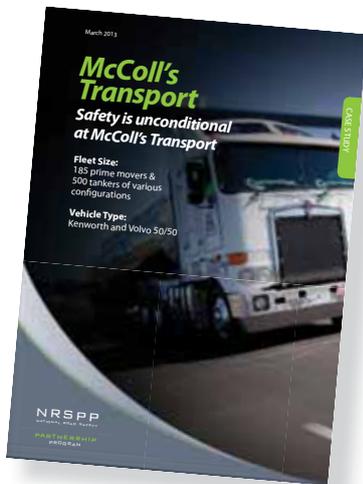
The compliance side is equally a huge task. I personally take my hat off to the heavy vehicle operators, knowing just how many state and national laws they must abide by. Especially when you consider anyone in Australia can become a heavy vehicle operator with the right driving license.

To operate a bar or restaurant a business requires a permit and staff also need a license to serve food and drinks. A compliance or service breach can result in the business being forced to close until the issues are rectified and if the breach is significant enough the business can be shut permanently. Such a model is common for the heavy vehicle industry internationally as it provides greater incentive to be compliant.

I am not advocating for heavy vehicle operator licensing but a discussion on the topic is needed; perhaps the absence of licensing disadvantages the safer operators.

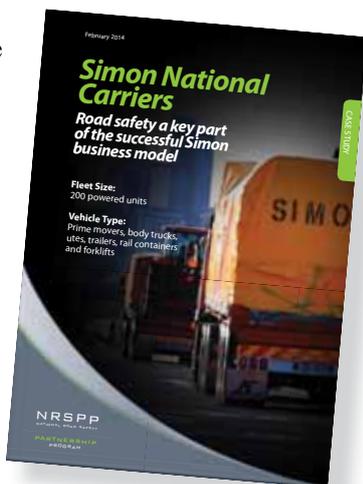
Truck drivers are professionals just like pilots

Good heavy vehicle drivers are incredible to see in action. They are so focused on their task, their surrounds and in particular what other road users are doing. In the NRSPP McColl's Transport Case Study the Chief Executive referred to them as being like airline pilots. The safety management system they established ensures they had the best drivers which were supported and trained along similar principles.



To illustrate just how good some heavy vehicle drivers are, there are a group of drivers who have travelled in excess of five million kilometres without an incident or speed infringement.

Let's put that into context, a line haul driver travels about 220,000 km per annum so it would take around 20 years to reach the five



million milestone. How many organisations are willing to accept a few speed breaches, infringements and other risky behaviour because, they argue, their driver's do 55,000km per annum and/or driving is essential for sales? There should be no difference.

Heavy vehicle drivers are only human as well but their skill level and professionalism should be recognised. A momentary lapse can have horrific consequences so a driver must be alert and focused at all times.

Appropriate speed

Managing speed is always a key factor for road safety, and for heavy vehicles it is all about appropriate speed. A heavy vehicle has a higher centre of gravity and a larger mass, and therefore road curvature, descent and turning can affect how the vehicle sits and travels on the road. A heavy vehicle can travel too fast for the conditions and still be below the posted speed limit.

A driver needs to consider what the load type is, how it can shift and where the centre of gravity is. A minor miscalculation or distraction for a few seconds at the wrong moment can see the heavy vehicle roll onto its side.

Interestingly the most exhausting phase for a heavy vehicle operator in the line-haul sector is leaving urban environments before entering the open roads.

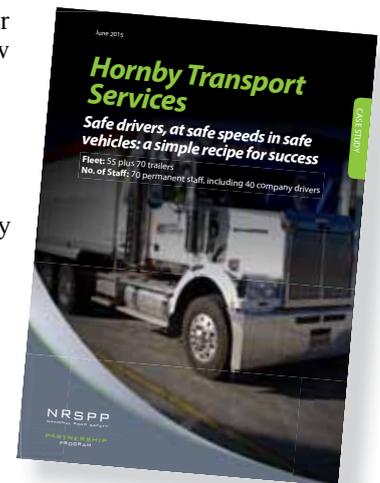
Many heavy vehicle drivers feel the pressure and stress of the environment of interacting with other often impatient road users.

The view of other road users is often that a heavy vehicle is a speed impediment or an opportunity to jump a lane, not recognising they are putting themselves at risk of becoming the 'speed bump'. Imagine though for truck drivers operating in the urban environment what the impact of this is as a day-to-day occurrence.

Fatigue, a symptom of poor sleep

Operating a heavy vehicle is a solitary task, especially for the line-haul drivers. As result, a key focus is ensuring the driver is 'fit to drive' and part of that includes being well rested before commencing driving.

When the heavy vehicle is underway the driver's fatigue is managed as per national regulations but do such regulations really recognise the drivers as human? Can we really regulate out the fatigue risk?



One compliance manager put it nicely, saying that if you're purely managing fatigue to be compliant, you will fail because you need to focus on actually managing the driver's fatigue and then you will naturally be compliant.

The focus should be on achieving good quality sleep and recognising the long term impacts of poor quality sleep. Good quality sleep is linked to more than just reducing fatigue but health issues such as weight loss, Type 2 diabetes and long term issues such as dementia. Striving for catch up sleep or sleeping longer is no solution as it is about regular quality sleep.



Reflections

Being a heavy vehicle operator is a difficult job and the good and safe drivers are in high demand. Managing the overall compliance of large fleets and their sub-contractors is equally tough but those focused on safety are passionate about improving the sector.

I find it a privilege to sit on the edge of the sector, to see the passion and openness that has been shared through the NRSP to improve the overall safety of the sector. There is no road safety "silver bullet" but a requirement for a holistic approach is required to continue raising the road safety standard of the sector. Collaboration and sharing of knowledge is the key.

We need all organisations throughout the supply chain to understand the long term value of road safety initiatives and actively link it into the business culture. This will save money and lives, over time. Sharing knowledge across sectors will also assist in broadening the understanding of how other road users should respect and interact with heavy vehicles.

NRSP

The National Road Safety Partnership Program has been established to assist organisations from all sectors to collaborate on common issues and share good practice road safety knowledge. The heavy vehicle sector is a key stakeholder of the program and has openly shared their approaches to road safety, implementation, lessons learned and the cost benefit.

NRSP partners all demonstrate how safety is part of their culture and that it shouldn't be viewed as a competitive advantage but a shared one. An organisation can do everything in its power to be safe but the road is an open environment. A piece of the road safety puzzle from one organisation which when shared with a peer could be the piece that saves their own driver from being involved in an incident with that peer.

The numerous NRSP case studies, webinars and working groups highlight this fact and demonstrates that improving road safety is simply good business. The NRSP aims to help organisations from all sectors recognise that road safety is not altruistic but has to pay its way. For more information please go to www.nrspp.org.au.

The NRSP is proudly managed by ARRB, with funding from the National Transport Commission, South Australian Motor Accident Commission, NSW State Insurance Regulatory Authority, Transport for NSW, VicRoads, TAC and ARRB.

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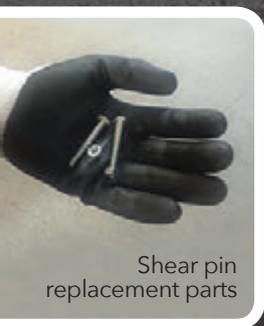
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