Vol 32, Issue 2, 2021

Journal of Road Safety

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Contributed Articles

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We all make mistakes. But there are changes we can make so simple mistakes don't end in tragedy.

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WAKA KOTAHI NZ TRANSPORT AGENCY / ROAD TO ZERO

New Zealand Government

National Road Safety Week

Take the pledge – drive so others survive

Road safety is a shared responsibility. Each year, approximately 1200 lives are lost and another 44,000 are seriously injured on Australian roads due to road trauma.

National Road Safety Week (16 -23 May 2021) highlights the impact of road trauma and the role we can all play by making choices that improve the safety of all road users. The week honours those who have been killed or seriously injured and creates opportunities for our community to contribute to reducing the number of deaths and serious injuries caused by crashes on Australian roads.

This year, we are asking people to visit the National Road Safety Week website and take the pledge to **lead the way and drive so others survive**. By taking the pledge you are making a commitment to take responsibility on the road to **protect every life, every time you drive**.

During National Road Safety Week, events are held across Australia and yellow ribbons are displayed to encourage drivers to check their own behaviour and 'Drive So Others Survive'.

Transport for NSW, through the Centre for Road Safety, are holding a number of events to commemorate the week including lighting up various landmarks across NSW yellow.

If you would like to get involved, please email **towardszero@transport.nsw.gov.au** and we will supply you with a creative toolkit to get you started. To find out more about what is happening in your area during National Road Safety Week, visit **roadsafetyweek.com.au**

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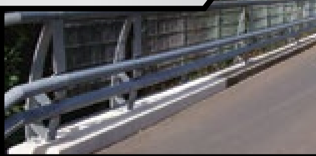

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Cover image

It is the 6th UN Global Road Safety Week between 17th and 23rd May 2021 with a focus on 'speed'. #Love30 calls on policy makers to act for low speed Streets for Life in cities, towns and villages where people mix with traffic (https://www.unroadsafetyweek.org/en/home). One of the many effective speed management interventions include mobile speed cameras. See how mobile speed camears can also manage speeds on rural roads in the Original Road Safety Research article: Cameron, M. and Newstead, S. (2021). "Increasing the effectiveness of mobile speed cameras on rural roads in Victoria based on crash reductions from operations in Queensland" *Journal of Road Safety*, 32(2), 16-21. Photo kindly provided by Queensland Police Service.

The Journal of Road Safety (ISSN 2652-4252 (Online); ISSN 2652-4260 (Print); DOI:10.33492/JRS (formerly **The Journal of Australasian College of Road Safety (JACRS)**, ISSN 1832-9497, DOI:10.33492/JACRS between 2005 and 2019 and **RoadWise** between 1988 and 2004). Published quarterly (February, May, August, November) by the *Australasian College of Road Safety*.

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All papers submitted to the JRS undergo a peer-review process, unless the paper is submitted as a Contributed Article or *Correspondence (Letter to the Editor)*. Peer-review Papers and Contributed Articles can take the form of the following articles types: *Original Road Safety Research; Road Safety Data, Research & Evaluation Methods; Road Safety Policy & Practice; Road Safety Case Studies; Road Safety Evidence Review; Road Safety Best Practice Guidance; Road Safety Theory; Road Safety Media Review; Perspective on Road Safety*.

All submissions are assessed on the basis of quality and importance for advancing road safety, and decisions on the publication of the paper are based on the value of the contribution the paper makes in road safety. Once a paper is submitted, the Editor-in-Chief and/or Managing Editor initially review the submission. Authors are notified if their paper is judged to be outside of the JRS' scope or lacks originality or message that is important to the readers of the JRS.

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Peer-reviewed papers

Original Road Safety Research

Modelling New Zealand Road Deaths

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This peer-reviewed paper was first presented as an Extended Abstract and Oral Presentation at the 2019 Australasian Road Safety Conference (ARSC2019) held in Adelaide, Australia and first published in the ARSC2019 Proceedings in the form of an Extended Abstract. It was expanded into a 'Full Paper' and underwent further peer-review by three independent experts in the field. It is being reproduced here with the kind permission of the authors and is now only available in this edition of the JRS.

Key findings

- After testing, three models were developed: an ARIMA and two ARDL models
- The variables correlated well: road deaths, GDP, employed, petrol price and young population
- An ARDL model proved the most promising and was used in projecting to 2025
- The ARDL model forecast showed road deaths fall slightly overall from 2018 to 2025.

Abstract

New Zealand is developing an integrated road safety intervention logic model. This paper describes a core component of this wider strategic research carried out in 2018: a baseline model that extrapolates New Zealand road deaths to 2025.

The baseline will provide context to what Waka Kotahi NZ Transport Agency is trying to achieve. It offers a way of understanding what impact interventions have in acting with and against external influences affecting road deaths and serious trauma.

The baseline model considers autonomous change at a macro level given social and economic factors that influence road deaths. Identifying and testing relationships and modelling these explanatory variables clarifies the effect of interventions.

Time-series forecasting begins by carefully collecting and rigorously analysing sequences of discrete-time data, then developing an appropriate model to describe the inherent structure of the series. Successful time-series forecasting depends on fitting an appropriate model to the underlying time-series.

Several time-series models were investigated in understanding road deaths in the New Zealand context. In the final modelling an autoregressive integrated moving average (ARIMA) model and two differing autoregressive distributed lag (ARDL) models were developed. A preferred model was identified. This ARDL model was used to project road deaths to 2025.

Keywords

ARDL, Baseline, Model, Forecast, Road deaths, Time-series.

Glossary

Road deaths: are defined in New Zealand as deaths occurring as the result of injuries sustained in a road crash within 30 days of the crash.

Road crash: is defined as an event involving a vehicle that results in damage to persons or property.

Road: is defined as a place where the public has legal access with a motor vehicle.

Note: In New Zealand prior to 2015 only those road crashes involving a motor vehicle were recorded. Since 2015 cyclist only road crashes resulting in death have also been recorded as road deaths.

Introduction

Waka Kotahi NZ Transport Agency is leading the development of an integrated road safety intervention logic model (2017) with sector partners including NZ Police, Ministry of Transport (MoT) and the Accident Compensation Corporation (ACC). The Integrated Intervention Logic Model (IILM) is a tool to inform strategies aimed at improving safety across the network. New Zealand is working to reduce road trauma by implementing current and proposed interventions. The model allows users to select a suite of actions and activities (the intervention) and prescribe the degree of each (the dose). The model then calculates potential deaths and serious injury (DSI) savings (the response) from that combination of interventions. The dependency, union, dominance or independent nature of the interventions are used in determining the combined effect. The model also accounts for changes in effectiveness of an intervention dependent on the dose and using a projected baseline, the effect of implementing over time.

The main aim of the study presented here is to model a baseline of road deaths in New Zealand from 2018 to 2025. It is considered that time-series models are appropriate for this purpose. However, it needs to be pointed out that time-series modelling is atheoretical: it concentrates on finding a specification that captures the observable dynamic behaviour of a series without necessarily requiring a theoretical explanation for that behaviour. Time-series models can be grounded in theory, and exogenous influences can be incorporated into these models, but these features are not essential. Many time-series models are best regarded as providing a useful approximation to complex, and perhaps not fully understood, real-world phenomena. They offer approximations that help us to predict future realisations and to estimate the impact of disturbances or interventions in the process (Becketti, 2013).

Time-series modelling is a dynamic area that has attracted the attention of researchers over the last few decades. The main aim of time-series modelling is to carefully collect and rigorously study the characteristics of a set of time-series to develop an appropriate model that describes the inherent structure of the data being modelled. This model is then used to generate future values for the series, i.e. to make forecasts. Time-series forecasting can thus be seen as the act of predicting the future by understanding the past. Due to the importance of time-series forecasting in numerous practical fields such as business, economics, finance, science and engineering, proper care should be taken to fit an adequate model to the underlying time-series. Successful time-series forecasting depends on appropriate input data and model fitting. A lot of effort applied by researchers over many years to develop valid models has improved forecasting accuracy.

Methodologies used to model road deaths vary widely and have included simple and multiple regression analyses, Poisson regression analyses, negative binomial regression models, logit and probit models, random parameters models, fuzzy logic models and ARIMA.

There is a large literature on factors that influence the underlying frequency of road trauma. A review of major studies carried out in New Zealand, Australia and selected overseas countries follows.

Literature

Exogenous factors

A change in the economic situation affects individuals' needs and opportunities for travelling, which in turn influence the risk of being killed or injured in a road crash. In order to understand how economic development or activity affects road safety, it is necessary to consider the whole chain of events. From the review of previous modelling above and the literature, several factors are advanced that affect road deaths: these are discussed below.

A downturn in economic activity leads to less travelling and hence less exposure to traffic and a decreased number of crashes. This is partly because people cannot afford to travel as much and partly because the downturn in economic activity leads to higher unemployment rates and therefore fewer journeys to and from work. Most of the reviewed papers concentrate on the travelling of households, but Tay (2001) and Haque (2003) state that freight also follows economic conditions. Likewise, an increase in petrol prices leads to reductions in travelling as households have less disposable income and vice versa.

Several researchers (Hakim et al.1991, Haque. 1993; Tay, 2003; Wagenaar, 1984) have stated that, in addition to a general decrease in travelling, economic factors may influence the distribution of travel across travel types as well as demographic groups. One theory is that travel for recreational purposes and leisure activities is influenced more than journeys to and from work if income is changed. Such trips are also connected with a higher crash risk, since they are more often undertaken in the evenings or at night. Another theory is that travelling in the evening or at night is riskier than travelling during the day due to lack of visibility, higher speeds and a larger proportion of tired, drunken or young drivers on the road. Longer holiday trips are also connected with an increased risk, since they more often than other trip types take place on roads with higher speed limits and in unfamiliar environments (Wiklund et al., 2012).

Tay (2003) states that increased income leads to increased demand for travelling in private vehicles instead of by public transport. This may also have a negative effect on road safety, since public transport travelling is generally safer than other types of travel.

The number of younger people in the population in the age group 15 to 24 has a significant effect on road deaths, as younger drivers are generally more inexperienced, drive less safe cars, have a higher crash risk and may take greater risks around the road network.

Time-series regression models

A number of studies have used a range of time-series regression models to understand road deaths and carry out forecasts. Below is a brief review of some of the studies carried out.

The Australian Bureau of Infrastructure, Transport and Regional Economics (BITRE, 2014) examined the trends in road deaths and injury rates (road deaths and injuries per billion vehicle kilometres travelled (VKT)) in 21 countries around the world. New Zealand was one of the countries investigated. For New Zealand, a model of the fatality rate was constructed using the all-occupant seat belt wearing rate, the percentage of fatally injured drivers over the blood alcohol limit, an index of the speed of the 85th percentile of urban and rural drivers and a dummy variable for the effects of new laws affecting drug users and young drivers. Additional dummies captured the effects of measures taken during the oil crises of 1973 through to 1986.

The BITRE report states that the regression model used produced a reasonable prediction of the change in levels of deaths over time. Regarding New Zealand road deaths, the report concluded that over the period the most significant influence was the increase in seat belt wearing. In addition, unemployment (from the mid-70s), alcohol control (from the mid-80s), and speed control (from the mid-90s) each had an effect.

While the report states that the analysis carried out was robust, there were several concerns with the methodology. It should be noted that the intercept and drug/youth variables were not statistically significant but overall, the model had a high R-squared of 0.98 which may suggest an autocorrelation problem. It is not stated whether autocorrelation tests were carried out and found to be acceptable. Also not stated is whether the variables were checked for stationarity or for being co-integrated.

The analysis carried out showed that road deaths would continue to decline, but with hindsight this was not the case. BITRE suggested that econometric modelling of road deaths or crashes using regression models is extremely difficult as there are many factors that affect road deaths and that identifying them and their inter-relationships (possibly non-linear) is complex.

Another Australian study (Burke & Teame, 2018) showed that low fuel prices and low unemployment were important factors in explaining the rise in Australia's annual road deaths. Using different functional forms, such as ordinary least squares and negative binomial regression models, the study presented macro-level estimates of the factors affecting road deaths in Australia.

It is important to note that the estimated coefficients for petrol prices and unemployment were negative numbers. The authors stated that the reduction of fuel prices might lead to an increase in road deaths via a range of mechanisms. For example, lower fuel prices encourage increased use of motor vehicles. This channel is relevant if the fuel price elasticity of VKT is negative, which is what one would expect. While the proximate causes of any individual crash may be factors such as speeding and distraction, an increase in the total distance driven should be expected to lead to a general increase in the underlying exposure of the population to road crash risks. As Litman (2018) writes "all vehicle travel imposes risks".

Reductions in fuel prices might contribute to increases in road deaths for several reasons relating to road use (Burke & Teame, 2018; Burke & Nishitateno, 2013; Sheehan-Connor, 2015). Conversely, Burke and Teame suggest that there are ways in which lower fuel prices might reduce the number of road deaths. They also point out that electrification and autonomation of the vehicle fleet may cause the link between oil prices and road safety to diminish in the long-term.

An earlier study by Wiklund et al. (2012) also showed that economic factors were important in explaining road deaths in Sweden. The study included a survey of statistical methods used by previous researchers describing the variables they used as indicators of the state of the market (economy). The most common variables were the unemployment rate or the number of unemployed, while level of industrial production measures such as Gross National Product (GNP) were used to a lesser extent. Based on these findings, a model including a time trend, vehicle mileage and the number of unemployed was fitted to a time-series of Swedish data. The results showed that an increase in unemployment was associated with a decrease in the number of road deaths.

A further reason advanced was that the state of the economy affects road users' travel patterns. Results showed that the number of road deaths and number of fatal crashes were higher and collision crashes were more frequent during periods of economic growth. No significant difference was found with respect to time of day, age or gender distribution. Wiklund et al. also investigated the idea that periods of economic growth may induce a higher level of stress in society.

In New Zealand the study by Scuffham and Langley (2002) examined changes in the trend and seasonal patterns in fatal crashes in relation to changes in economic conditions between 1970 and 1994. A structural time-series model was used to estimate quarterly fatal traffic crashes. The dependent variable was modelled as the number of crashes and three variants of the crash rate (crashes per 10,000 km travelled, crashes per 1,000 vehicles and crashes per 1,000 population). Independent variables included in the model were unemployment rate (UER), real gross domestic product (GDP) per capita, the proportion of registered motorcycles, the proportion of young males in the population, alcohol consumption per capita, the open road speed limit, and dummy variables for the 1973 and 1979 oil crises and the seat belt wearing laws. Real GDP per capita, UER and alcohol consumption were all significant and important factors in explaining the short-run dynamics of the model. In the long-run, real GDP per capita was directly related to the number of crashes, but after controlling for distance travelled it was not significant. The road policy factors appeared to have a greater influence on crashes than the role of demographic and economic factors.

Several studies commissioned by the NZ Ministry of Transport have also analysed road deaths in New Zealand (Deloitte, 2017; Infometrics, 2010 & 2013; Keall et al., 2012; Stroombergen, 2013). The Deloitte report for the NZ Ministry of Transport (Ministry of Transport, 2017) modelled the number of casualty crashes and found that the variables VKT, motorcycle registrations, enforcement and speeding were significant. The modelling estimated the impact that a 1% increase in each of the explanatory variables had on the number of crashes (in percentage terms) observed in a given week. For example, a 1% increase in the VKT was associated with a 2.5% increase in the number of crashes. Deloitte stated that the results suggest that crash risk is strongly influenced by VKT as a 1% increase in VKT is associated with a greater than 1% increase in the number of crashes. A 1% increase in the number of motorcycle registrations was also associated with a greater than proportional increase (1.6%) in the number of crashes. This may be the result of motorcyclists' relative vulnerability or simply reflect a buoyant economy. The authors acknowledged that unexplained factors not captured by the model also played a substantial role.

One of the most popular and frequently used stochastic time-series models is the ARIMA model. Commandeur et al. (2013) used an ARIMA model to analyse road deaths in Norway, the UK and France. Their first case study was of road deaths in Norway from 1970 to 2009. An ARIMA (0,1,1) model, without a constant term but including an exogenous variable representing time, was fitted on the log of the annual 1970 to 2009 Norwegian road deaths series. The model parameters were all significant and the residuals of the analysis were considered to be independent, as the diagnostic tests did not reveal any evidence against the assumptions.

In their second case study Commandeur et al. used a multiplicative ARIMA $(0,1,1)(0,1,1)_{12}$ model on the log of the monthly number of car drivers killed or seriously injured (KSI) in the UK. Dummy variables to account for significant events and petrol prices were also included in the model. The model diagnostics were satisfactory in the sense that all parameters were significant and that residuals could be considered to be independent. The values of the regression coefficients for this model indicated that a $100(e^{-0.298} - 1) = -21.8\%$ change in the number of UK drivers KSI from February 1983 onwards was observed and an elasticity of -0.298 in the number of UK drivers KSI compared to the petrol price was suggested. Therefore a 1% rise in the price of petrol was associated with a 0.30% reduction in the number of UK drivers KSI.

The third case study by Commandeur et al. used data from France (January 1975 to December 2000) to demonstrate that an ARIMA model with exogenous (explanatory and intervention) variables can be an efficient tool for analysing the aggregate number of injury crashes and deaths.

From the above cases studies, Commandeur et al. concluded that ARIMA models can be used to analyse the dynamics of a time-series and to extrapolate into the future. Their case studies also showed that explanatory and intervention variables can be included in ARIMA models and the additional corresponding regression coefficients can be estimated and interpreted.

New Zealand context

Developing a New Zealand baseline requires an understanding of local data and trends for example, the recent break in the downward trend in both road deaths and serious injuries. Figure 1. below shows that from 1990 to 2013 road deaths generally declined. However, this trend was reversed, as road deaths increased from 2014 onwards to 2017.

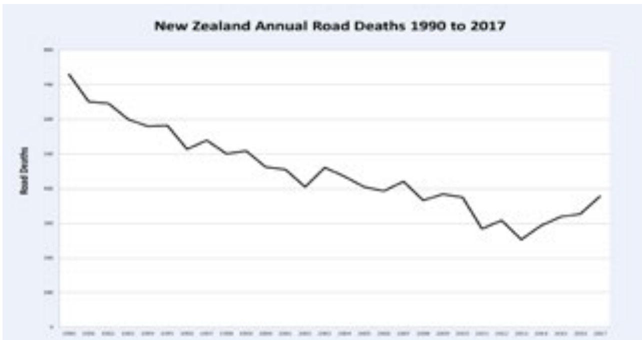

Figure 1: Fatal casualties and road deaths seasonally adjusted 1990 – 2017

From 2014 as DSIs increased, the household savings ratio also fell, suggesting an increase in private consumption and spending. The unemployment rate has decreased and vehicle use (Vehicle Kilometres Travelled, VKT) has risen over the same period.

On call interest rates dropped to a low in 2010. The NZ Treasury has held interest rates at a relatively low rate throughout this period. Building consents rose consistently since 2011 after a period of decline. ANZ Bank economic outlook forecasts of the value of the New Zealand dollar against our major trading currencies (Trade Weighted Index, TWI) were predicted to fall slightly in the next couple of years.

A Reserve Bank of New Zealand bulletin (Delbruck, 2005) suggested that any indirect effects of fuel prices on inflation and economic activity may be relatively large in New Zealand. Diesel has also been the main contributor to increases in New Zealand's oil use over the last decade and a half. It is suggested that the indirect effects of higher fuel prices, through an increase in the costs of providing public transport and other goods and services, may be more significant than in other countries. It was found that indirect effects on the Consumer Price Index (CPI) could potentially be quite sizeable, mostly relating to higher costs to transport services.

In recent years there has been an increase in the number of DSI crashes involving vehicles manufactured between 2004 and 2006. Vehicles older than this are already over-represented in DSI crashes. The change to importation of vehicles when stricter emissions requirements were introduced in 2002 may have had the effect of bringing in newer, but less safe, cheap vehicles that satisfied the emissions standard and were affordable: ongoing analysis at Waka Kotahi NZ Transport Agency suggest that there is evidence to support this.

The involvement of trucks in fatal crashes has changed little over the sample period 1990-2017. There is a wave with a period of around a decade evident in the time-series. This fits with financial cycles that are evident in data: there seems to be a 12-year cycle of financial lows and highs, within which there are regular fluctuations which are roughly either every six years or in three-year cycles.

Motorcyclist deaths remain constant annually with a definite seasonal pattern around summer use. The strong seasonality of motorcycle crashes when removed from fatal crashes makes the remainder of road deaths less seasonal.

The spike in New Zealand road deaths in 2017 was in part due to an increase in the number of cyclist deaths: there were 18 cyclist deaths in 2017 compared to the previous annual average of five. Similarly, pedestrian deaths in 2017 were also the highest annual total for over ten years. These factors combined in contributing to the overall upward trend.

It is not viable to use this level of detail in predictive analysis in the New Zealand context due to the relatively small numbers and random nature of these events. While this level of granularity is not considered in a macro level baseline, it is arguably necessary to be aware of it at least when developing one.

Data

Quality data at set intervals over a reasonable timeframe is necessary for the best predictive models. Much historical New Zealand data is available, collated on a quarterly basis. This was therefore used as the discrete-time interval in the model. Even then, some quarterly data that was available was estimated and often the methodology was not documented, while other datasets did not cover the period sought. Quarterly data was sought from 1990 to 2017, providing 112 data points.

A wide range of data was sourced from official sources:

- Accident Compensation Corporation, motor vehicle accident claims (2018)
- Ministry of Business, Innovation & Employment, energy prices - real and nominal price data relating to New Zealand's energy prices - petrol, diesel, fuel oil, natural gas and electricity (2018)
- Ministry of Health, publicly funded hospital discharges - series (2018)
- Ministry of Transport, RD006 vehicle kilometres travelled on state highways and local roads (2018)
- NZ Police, road policing driver offence data (2018)
- Reserve Bank of New Zealand, exchange rates and trade weighted index (TWI) (2018)
- Stats NZ, estimated resident population (2018)
- The Treasury, fiscal time series historical fiscal indicators 1972-2018 (2018)
- Waka Kotahi NZ Transport Agency, crash analysis system (CAS) (2018)
- Waka Kotahi NZ Transport Agency, transport data - VKT (2018).

An extensive range of data was gathered. Over 50 variables were collected and correlations between pairings of the variables covering the time period were tested.

Note that the criterion of using quarterly data from 1990 excluded the ability to use VKT, as VKT for 1990-1999 is not published. The current method of calculating VKT began in 2001. It is reported as quarterly data but is not seasonal, i.e. it does not reflect quarterly use nor is it seasonally adjusted. Quarterly published VKT is derived from annual vehicle odometer readings. The calculation involves distributing the count across the preceding four quarters while also incorporating an estimate for vehicles newer than three years that do not require annual testing. While national VKT provides a general measure of road use by motor vehicles, in isolation it does not capture the how and why. It was therefore decided to incorporate road use by considering economic and societal factors such as population, employed persons, petrol price and GDP as VKT is strongly correlated to these variables.

Analysis

Correlation

Correlation between pairings of variables was tested in Version 9.4 of SAS, Version 14.3 SAS/STAT (2016). The scatterplots below illustrate the correlation between pairings of those explanatory variables identified for investigative modelling, Figure 2.

The pairings demonstrating the strongest correlation were used in the investigative phase of modelling and are listed below.

The Pearson correlation coefficients, stronger than 0.7 or -0.7, suggest relationships between:

- GDP and road deaths
- Population and road deaths
- Employed (numbers of those in employment) and road deaths
- GDP and employed
- VKT and GDP
- VKT and employed
- Population and petrol price
- Population and GDP
- Population and employed
- Population and percentage of unemployed
- Trade Weighted Index (TWI) and GDP
- TWI and employed.

Variables

The key data used as explanatory variables in the final modelling in this study were:

- Road deaths
- Petrol prices
- Employed
- Young population (number of those persons aged 15 to 24 years)
- GDP expenditure.

Explanations for the relationships to road use and crash outcomes are discussed in the summary of literature above.

Adjustment

It is questionable whether road deaths have a seasonal pattern. Motorcyclist road deaths in New Zealand are clearly seasonal as previously noted, yet when removed from the total the remainder of road deaths have a greatly diminished overall seasonality. After much debate, it was decided to apply Seasonal Adjustment (SA) to road deaths as the other selected variables are seasonally adjusted.

Method

Several time-series models were investigated in understanding road deaths in the New Zealand context.

Dynamic models are constructed using time-series data, with combinations of differing lagged variables.

Figure 2: Scatterplots of the correlation between pairings of explanatory variables

The modelling goal is to reflect important interactions among the variables, accurately and concisely. In the final modelling an ARIMA (1,0,1) model and two different ARDL models were developed.

A difference between the ARIMA and ARDL model approaches is that ARIMA is univariate, where the lag of the dependant variable is used as an explanatory variable, whereas ARDL is multivariate, in that additionally it contains lags of the exogenous variables. The ARDL model is based on the belief that an action affects the dependant variable for some time into the future.

The exogenous variables used in the final modelling of road deaths as stated above were petrol price, employed, young population and GDP. All have strong Pearson correlation coefficients.

Testing the data

Before carrying out formal time-series analysis, it is necessary to undertake a series of tests to determine whether the data is stationary or non-stationary. It is important to determine this to avoid spurious regression, as results obtained when using independent non-stationary time-series may indicate a relationship between variables where no relationship exists.

Formally, a time-series Y_t is said to be stationary if (a) its mean and variance are constant over time and (b) the covariance between two values from the series depends on the length of time between them, rather than the actual times at which the values are observed.

Formal testing was carried out to confirm whether the time-series data were stationary or non-stationary. A number of tests can be applied such as the Augmented Dickey-Fuller (ADF) test (Dickey & Fuller, 1981), the DFGLS which calculates a modified Dickey-Fuller test (Elliot, Rothenberg & Stock, 1996) and the Phillips-Peron (1988) test. Of all the tests, studies have shown that the DFGLS test has significantly more power than the others. The DFGLS test was used when fitting our models.

Tests were applied to seasonally adjusted road deaths, petrol prices real and seasonally adjusted, GDP production and GDP expenditure, both real and seasonally adjusted, and employed real and seasonally adjusted. Road deaths seasonally adjusted data were stationary while all the other variables were non-stationary. This meant that the data could be modelled without the need to difference the data.

ARIMA analysis of road deaths

The ARIMA model is often used to model road deaths. Box and Jenkins (1976) developed a practical approach to building an ARIMA model, which best fits to a given time-series and satisfies the parsimony principle. Their concept has fundamental importance in time-series analysis and forecasting.

The Box-Jenkins methodology does not assume any particular pattern in the historical data of the series to be forecasted. Rather, it uses a three-step iterative approach of model identification, parameter estimation and diagnostic checking to determine the best parsimonious model from a general class of ARIMA models. This three-step process is repeated several times until a satisfactory model is finally selected. Then the model can be used for forecasting future values of the time-series.

The ARIMA (1,0,1) model test results showed the p values of the estimated coefficients are all statistically significant. The Q test shows no evidence that the residuals deviate from white noise. The cumulative periodogram generally remains close to the 45-degree line and well within the confidence bands; thus, the residuals do not exhibit any signs of non-random periodicity.

ARDL analysis of road deaths

In modelling road deaths given the data constraints, using stationary and non-stationary data with different levels of integration, a number of different time-series regression models were investigated using Version 14.2 of Stata (2015). The ARDL model was found to be a suitable functional form to explain and forecast road deaths.

In its general form, with *p* lags of *y* and *q* lags of *x*, the ARDL model can be written as:

$$y_t = \alpha_0 x_t + \alpha_1 x_{t-1} + \alpha_2 x_{t-2} + \dots\dots\dots + \alpha_q x_{t-q} + \beta_0 + \beta_1 y_{t-1} + \dots\dots + \beta p y_{t-p} + \varepsilon_t$$

where ε_t is a random «disturbance» term.

As noted earlier, while road deaths data are stationary, the other variables used previously in the ARIMA model (petrol prices, employed and GDP) are non-stationary. However, it was found in testing the output of the ARDL models that the data were cointegrated. In the ARDL model specification this involved testing whether the residuals of the estimated model are stationary. If the residuals are stationary, the estimated relationships are unlikely to be spurious as they are cointegrated.

The modelling approach adopted was to estimate a model with a set of possible explanatory variables and then successively eliminate statistically insignificant variables while considering the R-squared. Several ARDL model specifications were investigated and two models considered to be the most appropriate were identified.

The first ARDL model used mainly economic variables: petrol prices and unemployment. Both variables were statistically significant. The Engle- Granger test indicated that the variables were cointegrated and various tests carried out showed no autocorrelation (LM, Durbin-Watson and Residual Correlogram). The second ARDL model had in addition a demographic variable, persons in the younger age group between 15 and 24 years. This showed that all the variables were statistically significant, cointegrated and not autocorrelated. The R-squared for ARDL model 1 is 0.7861 and for ARDL model 2 it is 0.8008.

Results

The ARIMA model (1,0,1) forecast indicates that road deaths will continue to rise from 2018 to 2025, influenced by the recent rising trend from 2014 to date and the spike in 2017. These recent factors do not reflect the time-series. The results show that the ARIMA model underestimated road deaths, on average by around five percent.

Both ARDL models forecast a flattening trend in road deaths: a slow rise early in the forecast period followed by a decline. This has now been seen to have happened since completing the modelling.

The ARDL model 2 differs from ARDL model 1 as it includes a demographic variable: population of persons aged 15 to 24. ARDL model 2 shows that, in addition to the economic variable (petrol prices) and socio-economic variable (employed), the number of people aged 15 to 24 in the population is correlated with road deaths. Including this demographic variable produced in ARDL model 2 a higher R-squared value and it is therefore the preferred model.

ARDL model 2 results

Table 1 summarises the ARDL model 2 specification. Tables 2, 3, and 4 show the test results of this model.

Forecasting with the ARDL models

The reliability of the forecast is dependent on the accuracy of forecasting future youth population, petrol prices and employment numbers. The limitations of all these forecasted values of explanatory variables is that they are strongly influenced by exogenous factors that cannot be modelled. Petrol prices are the most volatile. That said, the historical data for 1990 to 2017 shows price trend has moved relatively consistently and variance has been bound by market forces without dramatic disruptive changes.

The approach taken in forecasting these explanatory variables was to use the Holt-Winters algorithm, a seasonal exponential smoothing algorithm (ETS AAA)

Table 1. ARDL model 2 summarised

Variable	Coeff.	Std. Err	P-Value	95% CI
Lag 1 log road deaths seasonally adjusted	0.2952571	0.0921223	0.002	0.1126157 0.4778984
Lag 1 log petrol price real and seasonally adjusted	-0.5380974	0.1360431	0.000	-0.8078161 -0.2683786
Lag 1 log employed seasonally adjusted	-1.171861	0.2040765	0.000	-1.576463 -0.7672598
Lag 1 log population aged 15-24 years	1.308681	0.4113065	0.002	0.4932258 2.124136
Constant	15.62295	2.421833	0.000	10.82143 20.42447
Adjusted R-squared	0.8008			

Table 2. ARDL model 2, Engle-Granger cointegration test

Test Statistic	1% Critical Value	5% Critical Value	10% Critical Value
Z(t) -11.029	-3.507	-2.889	-2.579

Table 3. ARDL model 2, Breusch-Godfrey LM test for autocorrelation

Lags (p)	chi^2	Df	Prob > chi^2
1	1.585	1	0.2080

Table 4. Durbin's alternative test for autocorrelation

Lags (p)	chi^2	Df	Prob > chi^2
1	1.521	1	0.2174

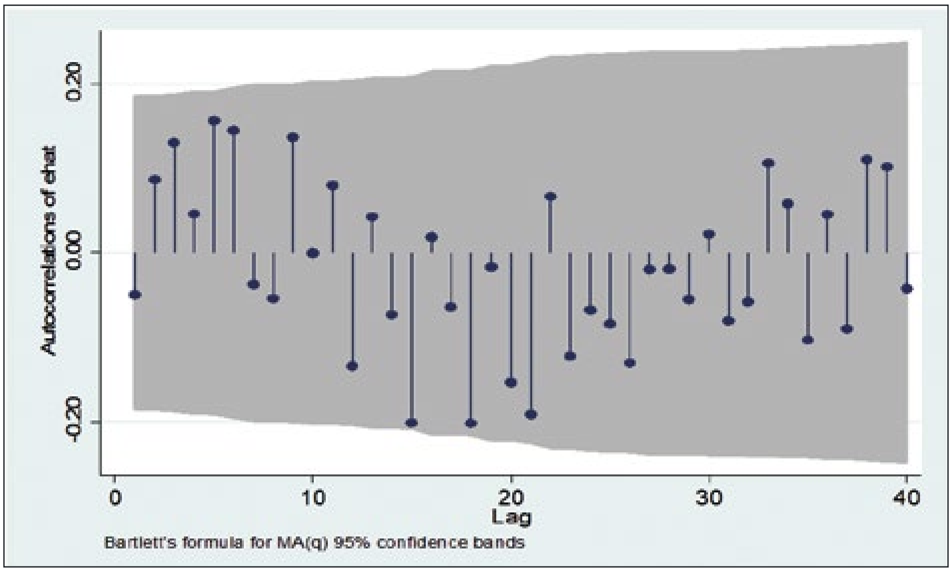

Figure 3. Residual correlogram of ARDL model 2

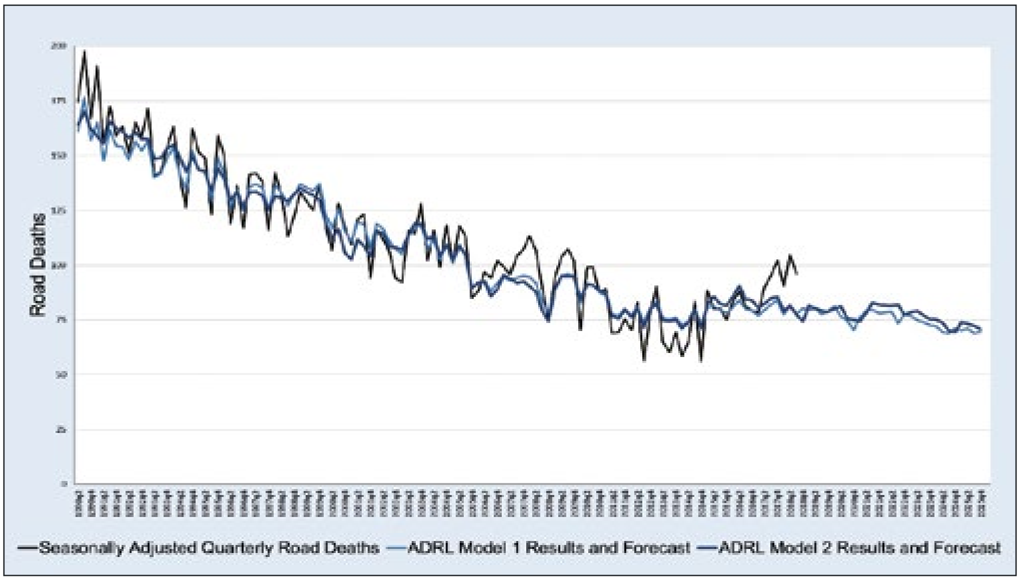

Figure 4. Results of ARDL Models 1 and 2 plus quarterly forecasts 2018 to 2025

and harmonic analysis of unique longer waveform periods of each variable. The forecast variables were used in conjunction with the ARDL model 2 coefficients to forecast quarterly road deaths to 2025.

ARDL model 1 and model 2 quarterly results and forecasts

Table 5. shows the modelled results from 2014 to 2017 and forecast results of both models from 2018 to 2025 for annual road deaths.

For use in Waka Kotahi NZ Transport Agency's IILM, rather than offering various scenarios for a predicted baseline to 2025 based on differing assumptions around future values of the explanatory variables, the approach taken was to forecast the 95%CI scenarios of the variables using ARDL Model 2. This confidence band of quarterly values for the period to 2025 was used in predicting annual road deaths for the baseline.

The values for the IILM baseline from 2018 to 2025 are listed below and illustrated in Figure 6. The values are presented as a range, the span is five percent of their value and they lie within the upper 95%CI model forecast.

2018 343-359 (actual 377)

2019 351-367 (actual 352)

2020 342-358 (actual 318, the Covid-19 NZ-lockdown effect is calculated at -10%)

2021 349-365

Table 5. ARDL Models 1 and 2 Forecast

Year	Annual road deaths	Model 1 Forecast	Model 2 Forecast
2014	293	298	296
2015	319	319	331
2016	327	324	344
2017	378	322	333
2018	*377	316	312
2019	*352	316	319
2020	*318	303	311
2021		313	317
2022		308	322
2023		298	310
2024		281	288
2025		280	290

*Post modelling the counts are now known to 2020, Covid-lockdown effect 2020 is est. -10%.

2022	352-370
2023	341-357
2024	317-330
2025	319-334.

This sequence is to be used as the baseline in Waka Kotahi NZ Transport Agency's integrated road safety intervention logic model.

Conclusion

The view taken in this study was to approach modelling by assuming nothing; to seek quality data that covered a long enough period to be useful; and to test everything.

As one would expect none of the models capture the extreme spikes, peaks and troughs across quarters. However, the fit of all three models across the 28-year time-series was shown to be good. The use of economic and societal factors of youth population, employed persons, petrol price and GDP proved valid in modelling road deaths.

The selected ARDL model was, after much trial and experimentation, identified as the preferred time-series approach for forecasting road deaths in New Zealand.

The predicted results have now been exposed, and with 2018, 2019 and 2020 counts now known, the projection from this ARDL model looks to be a valid baseline for the road safety integrated intervention logic model (IILM) being developed in New Zealand.

The IILM is a tool developed by Waka Kotahi NZ Transport Agency in partnership with key road safety partners. It is used to calculate the potential reductions in deaths and serious injuries that could be achieved through a combination of evidence-based interventions that can be reliably modelled.

A key objective of the model is to show how investment in road safety through the National Land Transport Programme can be optimised, i.e. to give greater assurance that we are investing in the right safety interventions, in the right combination and at the right levels. The

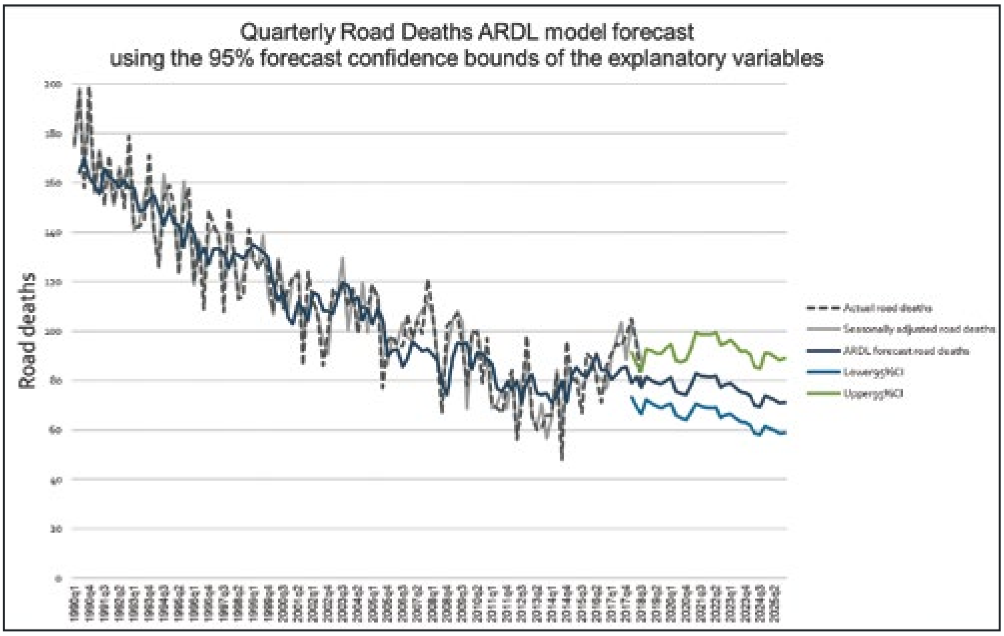

Figure 5. Forecast model using 95%CI scenarios of variables

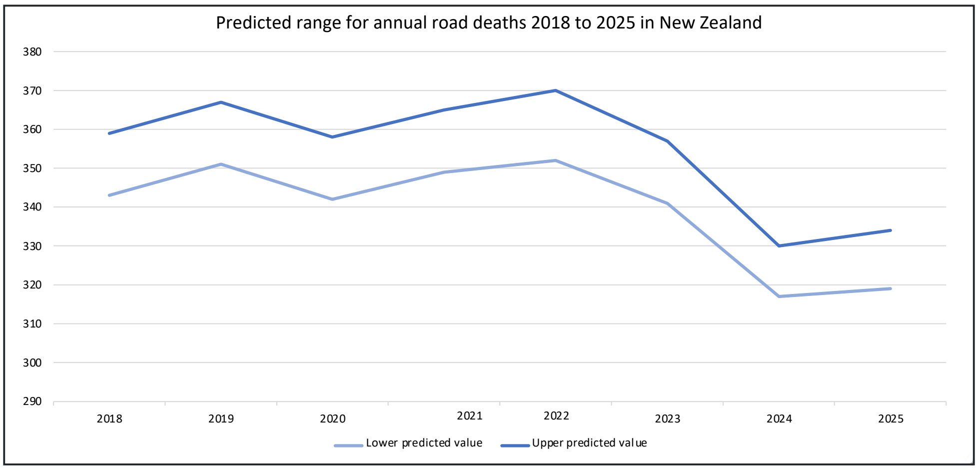

Figure 6. Predicted annual road deaths 2018 to 2025 for a baseline

interventions modelled are in addition to existing levels of investment and effort in road safety.

The IILM is nearing completion and this strategic tool has been used for assessing the DSI reductions and costs from suites of road safety activities, interventions and programmes. It was used in the target setting of the NZ Governments road safety strategy for 2020-2030, Road to Zero.

Acknowledgements

A special mention and thanks to Prof. Keall for undertaking peer review of the research.

Michael Keall, Department of Public Health, BA (Hons), PhD (Injury Epidemiology). Research Associate Professor; Co-director of He Kainga Oranga/Housing and Health Research Programme.

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Increasing the effectiveness of mobile speed cameras on rural roads in Victoria based on crash reductions from operations in Queensland

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This peer-reviewed paper was first submitted as an Extended Abstract and an Oral Presentation was recommended by two reviewers at the 2021 Australasian Road Safety Conference (ARSC2021) to be held in Melbourne, Australia in September. The two Reviewers also recommended that the Extended Abstract be expanded into a 'Full Paper' and undergo further peer-review as a journal submission by three independent experts in the field. The Extended Abstract will be published in the ARSC2019 Proceedings with a link guiding readers to this 'Full Paper' version which is being reproduced here with the kind permission of the authors and will only be available in this edition of the JRS.

The original text of this paper was included in MUARC's submission to the Inquiry Into the Increase in Victoria's Road Toll during 2019 conducted by the Economy and Infrastructure Committee of the Parliament of Victoria. MUARC's submission was published on the Committee's website and is protected by parliamentary privilege. The paper has been peer-reviewed by three independent experts in the field and some clarifications were added.

Key Findings

- Mobile speed cameras operating on rural roads in Victoria could be more effective in reducing serious crashes if operations reflected experience in Queensland.
- The Victorian Government's decision to increase mobile speed camera hours by 75% is an opportunity to increase rural sites and randomly schedule camera visits. This has been found to be an important attribute of mobile speed cameras in Queensland.
- The operations at the new rural sites could be expected to save 22.5 fatal crashes and 172 serious injury crashes per year in Victoria.
- Savings in social costs of crashes would exceed 45 times the cost of camera operations.

Abstract

Mobile speed cameras on Victoria's rural roads are not as effective as they could be due to the site selection criteria, the limited number of sites, and the visibility and predictability of their enforcement operations. Queensland's overt mobile speed cameras achieve substantial crash reductions up to 4 km from rural camera sites due to site selection based only on crash history and randomised scheduling of operations to those sites. New sites in Victoria should be selected as in Queensland and camera visits should be randomly-scheduled. The Victorian Government's announcement to increase mobile speed camera hours by 75% should take the form of at least 75% increase of rural sites. The new sites should be selected on the basis of a serious crash history within 2.5 km. Mobile speed cameras operated at these new rural sites could be expected to save 22.5 fatal crashes and 172 serious injury crashes per year.

Keywords

Speed camera, mobile, rural, covert, overt, random

Background

Automated speed enforcement in Victoria takes the form of camera-based units at fixed locations or movable camera units covering many locations for short shifts. The fixed cameras are either:

- Fixed spot-speed cameras on freeways measuring speeds at the spot,
- Point-to-point (P2P) cameras at each end of a freeway section, measuring average-speeds over the section, or
- Red-light/speed cameras at signalised intersections measuring spot-speeds on an approach road as well as red-light running offences.

The movable cameras are either:

- Mobile speed cameras (MSC) measuring spot-speeds at each road location they are moved to for a period typically of 2-3 hours, or

- Mobile P2P camera units measuring average-speeds over each pre-defined road section for a shift period yet to be defined [mobile P2P cameras are being trialled in some Australian States but have yet to be introduced].

Research has found that the fixed camera systems have very limited range of effect on speeds and crashes around the locations operated, except in the case of fixed P2P camera operations where the effect is over the whole freeway section (Gains, Nordstrom, Heydecker and Shrewsbury 2005; ARRB 2005; Newstead, Diamantopoulou, Cameron and Candappa 2017).

In the case of mobile spot-speed cameras, the effect on speeds and crashes can extend well beyond the locations operated (Cameron and Delaney 2006, 2008; Wilson, Willis, Hendrikz, Le Brocque and Bellamy 2010). This is because, in Victoria, MSCs are operated covertly from unmarked standard vehicles without signage on the approaches and are relatively unpredictable, especially in urban areas. Other Australian States (e.g. Queensland and Western Australia) have achieved broad effects of their relatively-overt MSCs by operating them at many more sites than Victoria and randomly-scheduling site visits to increase unpredictability.

Mobile speed cameras (MSC) on rural roads in Victoria

Sites for operation of mobile speed cameras in Victoria are chosen and operated according to both a set of site selection criteria based on a serious crash or speeding history or unsafe behaviour, and a set of physical field criteria, dictating the suitability of a site for siting and operation of a mobile camera unit.

The Victorian Auditor General's Office (VAGO 2011) conducted a review of the Victorian traffic camera program. They identified research evidence supporting the siting of mobile speed cameras using sites based only on physical criteria, but not necessarily on demonstrated crash or speed risk at the site as specified in the site selection criteria. This is because the primary purpose of the Victorian mobile camera program is to create a general, area-wide effect – the perception by drivers that the program could be in operation anywhere at any time so as to encourage universal compliance with speed limits. This is in contrast to the fixed speed camera program which is designed to deter speeding only in an area local to the camera. VAGO considered that there are factors that have led the mobile speed cameras in essence becoming an extension of the fixed camera program, especially on rural roads.

VAGO (2011) expressed a concern that use of narrow site selection criteria can limit the extent to which siting of mobile cameras has an area-wide effect, particularly if the number and spread of sites across the network is insufficient. It also noted that if there is a systematic pattern of deployment of mobile cameras, regular road users can identify this and adjust their behaviour according to their knowledge of where a camera is likely to be. As the perceived risk of detection falls, the deterrence effect of mobile cameras is also diminished. (The deterrence effect over a broad area relates to a speeding driver perceiving detection anywhere at any time.) It noted that siting of mobile camera operations based on physical criteria alone might reduce the likelihood of an identifiable pattern and therefore potentially heighten the level of area-wide effect. This approach would also increase the number of sites available for cameras which had been diminishing over time due to development of the surrounding environment, thus excluding sites based on the necessary physical criteria.

Trial of alternative operations and additional MSC sites

In response to a VAGO (2011) recommendation, Victoria Police conducted a trial of mobile speed camera deployments based only on the physical field criteria during 2014-2015. In three Police Divisions, the number of MSC sites was approximately doubled by choosing new sites without any constraint to needing a history of serious crashes or speeding in the vicinity. The total hours of operation of MSCs in each Division continued unchanged.

The analysis found about 5% reduction in casualty crashes in the lower speed limit zones (up to 60 km/h) of the trial Divisions (Cameron, Newstead and Budd 2019). There was no evidence of an effect on crashes on roads with higher speed limits, principally rural roads. It was concluded that there was no advantage in relaxing the site selection criteria (based on serious crash or speeding history) for MSC sites on higher speed limit roads in Victoria. However, nor is there a disadvantage in increasing the number of MSC sites on these roads and spreading the total hours of MSC operation over all sites in a Division (approximately halving the intensity per site). The "covert" MSCs may still be visible and obvious on typical higher speed limit roads in Victoria, but an increase in MSC sites leads to a broader coverage of the road system because the local effects of MSC operations multiply.

Experience with the operation of overt MSCs in Queensland indicates how the local effects of Victorian MSCs on rural roads can achieve a broader distance-halo of influence around MSC sites than current operations and maintain a longer-term local effect than that just during MSC presence at each site. The Queensland experience and research are outlined in the following section.

Local effects of Queensland's mobile speed cameras

Queensland MSCs are randomly scheduled to approved sites within the camera operator's Police District prior to each shift commencing, with the intention of reducing the predictability of camera placements. MSC sites are located after identifying an area with diameter of one kilometre (urban regions) or five kilometres (rural regions) in which at least two "speed camera criteria" crashes have occurred during a previous five-year period. "Speed camera criteria" crashes are defined as either:

- Speed-related crash (i.e. reported by Police as exceeding the speed limit, or excessive speed for the circumstances), or
- Serious casualty crash (i.e. resulting in death or hospitalisation) not at an intersection, or
- Either an "out of control" or "off path on curve" type of crash.

Newstead, Budd and Cameron (2017) and Cameron, Newstead and Budd (2017) estimated the local crash effects each program year from 2008 to 2015 (Table 1). The zones of influence considered in the analysis were up to 1 km from camera sites in urban areas and up to 4 km from sites on rural roads. In the period analysed, MSC operations grew from 5,640 to 8,980 hours per month at 3,134 active sites during 2015.

The crash effects of Queensland MSCs in rural areas are of greater interest to Victoria than urban areas because Victoria's covertly-operated MSCs are known to have strong general effects on urban crashes and their injury severity (Cameron, Cavallo and Gilbert 1992).

Table 1 shows the estimated crash reductions within 4 km of the rural MSC sites during 2008 to 2015. The rural MSC hours per month were reduced during 2014 and 2015 from the relatively high level during 2013. The reductions in serious casualty and all casualty crashes near rural MSC sites were also substantially lower during those years compared with reductions during 2013. The crash effects within 4 km during 2013 represent more typical effects, namely 41% reduction in fatal crashes, 30% reduction in serious casualty crashes and 27% reduction in all casualty crashes.

Transportability of Queensland experience to Victoria's rural MSCs

It is suggested that the effects of Queensland's MSC program on rural roads could be used to estimate that at new MSC sites on Victoria's rural roads if:

New sites were chosen by having at least two serious casualty crashes within 2.5 km during a recent five-year period as the principal criterion

MSC sessions are randomly scheduled to all new sites within each operator's area during each operator's shift

Each new site is visited and operated for at least 35 hours per site per year, the average intensity per site in Queensland during 2015.

With these MSC site selection, scheduling and visitation characteristics, it is expected that crashes would be reduced within 4 km of rural sites by the percentages shown in Table 1. It is acknowledged that there is a substantial difference in the sizes of the rural areas of Victoria and Queensland, but the transportability of the Queensland

Table 1: Estimated local effects measured at Queensland MSC sites in urban and rural areas within 1 km and 4 km analysis halos, respectively. Year, MSC hours per month, and percentage reduction in crashes (Newstead et al 2017; Cameron et al 2017)

Years	Hours per month		Fatal crashes		Serious casualty crashes		All casualty crashes	
	Urban	Rural	Urban	Rural	Urban	Rural	Urban	Rural
			0-1 km	0-4 km	0-1 km	0-4 km	0-1 km	0-4 km
2008	3999	1639	41.3%	22.4%	19.6%	28.7%	19.8%	23.3%
2009	4051	1550	51.3%	11.2%	24.1%	20.6%	26.3%	19.4%
2010	4458	1729	56.6%	23.8%	25.6%	21.0%	28.1%	15.9%
2011	4608	1651	49.4%	39.1%	26.0%	25.2%	29.4%	23.2%
2012	4911	1558	49.5%	31.6%	27.4%	25.0%	33.4%	25.4%
2013	6354	1749	70.3%	41.3%	29.3%	29.5%	32.0%	27.4%
2014	6849	1489	67.5%	42.3%	32.7%	17.6%	34.1%	14.7%
2015	7483	1497	61.0%	33.5%	32.8%	14.5%	33.3%	10.6%

experience seems reasonable if the operational characteristics of Queensland MSCs are maintained in Victoria.

Current MSC operations at existing sites in rural Victoria are expected to influence crashes at most 1 km from each site, in a similar way as a fixed speed camera at the site. This is because existing MSC sites have probably become well known, the presence of an MSC is predictable, and when present the “covert” MSC vehicle is probably visible from a substantial distance, allowing the driver to correct any speeding. It is not known whether the random scheduling of MSC sessions to existing sites would overcome their predictability and increase their effect halo. However, the existing rural sites are currently visited for more than 44 hours per site per year which exceeds the Queensland visitation rate.

Estimated crash effects of new rural MSC sites in Victoria

During December 2013, there were 1079 rural MSC sites and 910 urban sites in Victoria. These were increased by about 300 sites during the trial of alternative operations in 2014-2015, but it is understood that the number has returned to pre-2014 levels following the completion of the trial.

In May 2019, the Victorian Government announced plans to increase the operational hours of MSCs by 75%. On rural highways, this should take the form of an increase in MSC sites. If these new sites are selected, scheduled and visited by MSCs as in Queensland, then it could be expected that they would reduce crashes over 8 km sections centred on the sites (Cameron and Newstead 2018).

All 8 km sections of rural category A divided roads and A, B and C undivided roads in Victoria were ranked by their number of serious crashes during 2006-2015 (10 years). This provided a stable indicator of the relative crash problem on these sections. The 75% increase of the existing rural MSC sites, namely 810 new sites, was distributed over the four categories of rural roads in proportion to their length. The highest ranked 8 km sections within each road category were selected as potential new MSC sites near the centre of each section (subject to constraints due to physical field criteria).

Table 2 shows the estimated savings in crashes of each severity if MSCs were randomly scheduled to operate at each of these new sites for at least

Table 2: Crash savings per year, Human Capital cost savings, BCR and marginal BCR from 75% increase in new sites for randomly-scheduled overt mobile speed cameras (MSC). Also estimated effects of 10 new sections for mobile P2P cameras.

Rural road type	Length (km)	Enforce-ment type	Percent increase in sites*	New sites (or P2P sections)	Increase in hours per year	Fatal crashes saved per year	Serious injury crashes saved per year	Minor injury crashes saved per year	**Crash cost saving per year ($m)**	**Total additional cost ($m pa)**	**BCR** (Increase benefits/ increase costs)	Marginal BCR
Divided A Roads	418	Overt MSC	New site	18	617	3.00	51.89	112.34	45.910	0.087	**524.97**	353.04
Undivided A Roads	2,606	Overt MSC	numbers	110	3,848	4.04	24.63	28.13	28.122	0.545	**51.58**	24.16
Undivided B Roads	3,907	Overt MSC	distributed by road	165	5,769	5.01	29.53	33.28	34.142	0.817	**41.77**	14.21
Undivided C Roads	12,252	Overt MSC	length	517	18,090	10.42	65.85	75.57	74.158	2.563	**28.93**	4.56
All Highways A-C Total	**19,183**	**Overt MSC**	**75%**	**810**	**28,324**	**22.48**	**171.90**	**249.32**	**182.332**	**4.013**	**45.43**	**16.78**
All Highways A-C	19,183	Mobile P2P cameras	New sections	10	350	1.91	15.10	14.49	15.664	0.431	**36.37**	28.45

* Increase from 1079 rural MSC sites operated for 48,091 hours per year during 2013 and essentially unchanged during 2014-2018

35 hours per year (e.g. 14 visits at 2.5 hours per visit). It is likely that there is a greater focus of the proposed new sites onto category B and C roads than existing MSC sites in Victoria. While these roads are more lightly trafficked than category A roads, they still cover a substantial proportion of serious crashes due to their length. In total, the 8 km sections cover 34% of the total length of each rural road category.

The estimated annual savings in crashes across the road sections influenced by MSC operations at the new sites are 22.5 fatal crashes, 172 serious injury crashes and 249 minor injury crashes. The benefit-cost ratio (BCR) of the social cost savings, based on Human Capital costs of crashes, compared with the costs of camera operations, would be 45. The marginal BCR of further increases in new sites would be nearly 17, indicating that more than the 75% increase in rural sites would be warranted.

Mobile P2P cameras

Table 2 also shows estimated crash savings if mobile point-to-point (P2P) [average-speed] cameras operated on rural highways, covering ten sections of category A-C roads, the number chosen only to illustrate effects (Cameron and Newstead 2018). Mobile P2P camera units are a new technology that makes use of two units parked at the terminals of a carefully-surveyed road length to measure the average speed in the same way as fixed P2P camera systems. Each unit could be either vehicle- or trailer-based. It is expected that each one-way section will need to be visited on average for 35 hours per year, as visited by the mobile MSCs in rural Queensland, to produce a long-term time-halo effect along each section in a similar way as the effect produced by a fixed P2P system operating continuously.

No mobile P2P cameras yet operate in Victoria. It is envisaged by the authors that in suitable rural road environments, long sections would be selected, longer than the halo of influence of each spot-speed MSC. Sections typically 20 km in length would be ranked by their serious crash rate per kilometre and the top ranked sections selected (Cameron and Newstead 2018).

In Table 2, the estimated effect of mobile P2P was analysed by initially considering the ten highest-ranked 20 km sections of rural roads. An allowance of $20,000 per annum was made for the establishment and maintenance of each surveyed road section. Two P2P mobile camera units would be required to enforce each mobile P2P hour, but the cost to process each average-speed offence was assumed to be the same as those detected by a spot-speed MSC. While expensive to operate, mobile P2P has the potential to cover long rural road sections, longer than can be covered by spot-speed MSCs, and achieve benefits well in excess of the costs.

Conclusions

- Mobile speed cameras on Victoria's rural roads are not as effective as they could be due to the site selection criteria, the limited number of sites, and the visibility and predictability of their enforcement operations.
- Queensland's overt mobile speed cameras achieve substantial crash reductions up to 4 km from rural camera sites due to site selection based only on crash history and randomised scheduling of operations to those sites.
- Victoria's mobile speed cameras could achieve crash reductions over 8 km sections of rural roads ranked highly by their serious crash history. New sites should be selected as in Queensland and camera visits should be randomly-scheduled to each site for shifts totalling at least 35 hours per year.
- The Victorian Government's announcement to increase mobile speed camera hours by 75% should take the form of at least 75% increase of rural sites. The new sites should be selected on the basis of a serious crash history within 2.5 km and should consider all category A, B and C rural roads.
- Mobile speed cameras operated at these new rural sites could be expected to save 22.5 fatal crashes and 172 serious injury crashes per year. Social cost savings would exceed 45 times the cost of camera operations.
- While still a new technology, mobile point-to-point camera units have the potential to enforce speeding over much longer rural road sections than the traditional spot-speed mobile cameras.

Acknowledgments

The research on which this paper is based was carried out for the Queensland Department of Transport and Main Roads and under MUARC's Baseline Research Program for which grants have been received from the Department of Justice and Community Services, VicRoads (now Department of Transport), and the Transport Accident Commission in Victoria.

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An Evaluation of Retro-Reflective Screens to Aid Conspicuity of Freight Trains at Passive-Control Level Crossings

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This peer-reviewed paper was first submitted as an Extended Abstract and an Oral Presentation was recommended by two reviewers at the 2021 Australasian Road Safety Conference (ARSC2021) to be held in Melbourne, Australia in September. The two Reviewers also recommended that the Extended Abstract be expanded into a 'Full Paper' and undergo further peer-review as a journal submission by three independent experts in the field. The Extended Abstract will be published in the ARSC2019 Proceedings with a link guiding readers to this 'Full Paper' version which is being reproduced here with the kind permission of the authors and will only be available in this edition of the JRS.

Key Findings

- Freight trains are difficult to see at level crossings in rural areas at night;
- Retro-reflective screens that reflect vehicle headlights could improve visibility;
- Effectiveness of a prototype screen was evaluated using a reaction time experiment;
- Screen led to shorter reactions (increased visibility) with high beam headlights;
- But longer reactions (reduced visibility or maybe confused drivers) with low beam.

Abstract

Freight trains already passing through level crossings in rural areas at night can be difficult for approaching motorists to see. Crashes can occur if the crossing has 'passive' controls (Give way/Stop signs) and motorists fail to stop. Retro-reflective screens on the far side of the crossing to motorists that reflect headlights and produce a 'strobing' effect between carriages could increase train conspicuity. A prototype screen was applied to a crossing in South Australia. Four videos of freight trains at night from the perspective of an approaching vehicle (conditions: high versus low beam headlights, screen versus no screen) were recorded and used in a reaction time experiment with N=29 drivers. Mean reaction times to the four videos were examined using multivariate analysis of variance. Results were mixed. With high beam headlights, the screen led to shorter reaction times, which suggests it increased train visibility. With low beam headlights, it led to longer reaction times, which suggests it reduced train visibility or that it confused drivers. The detrimental effect of the screen with low beam headlights could be, at least partly, due to methodological limitations relating to differences between trains in the videos, the instructions given to participants, and the degree to which the experiment replicated real-world driver behaviour. However, the screen may genuinely have confused or distracted participants and may do so in real-world conditions. Further experimental testing would be required to determine whether the results in low beam conditions persist when potential methodological limitations are addressed.

Keywords

Trains, Passive-control level crossings, Rail safety, Reaction time experiment, Retro-reflective treatment

Introduction

In urban areas of Australia level crossings between railways and roads have 'active' controls (flashing lights, warning sounds and boom barriers) that are activated by track circuitry in response to an approaching train. However, many level crossings in rural areas have 'passive' controls (Give way or Stop signs), which require road users to look for trains and decide whether they are safe to cross the rail corridor.

The issue with passive crossings is the potential for human error. If a motorist fails to stop and check for trains a crash may occur. Trains (specifically freight trains) can be difficult to see at night in rural areas as there may not be any artificial lighting at the crossings and trains often have no lights or retro-reflective material on their sides, making it difficult to see a train already passing through the crossing when a vehicle approaches. Trains are also relatively infrequent in rural areas and drivers may become accustomed to not seeing one, assume the crossing is clear and drive straight through. These factors increase the risk of a collision. Research in Australia by Tey, Ferreira and Wallace (2011), which examined driver behaviour in video recordings at level crossings and in a driving simulator, showed that driver responses to passive crossings are poor compared to active crossings in terms of stopping compliance, approaching speeds and final braking position. Similarly, simulator research in Australia by Rudin-Brown, Lenné, Edquist and Navarro (2012) showed that crossing violations were less likely at active crossings than passive crossings. There are approximately 6,000 passive level crossings in Australia (Australian Transport Safety Bureau, 2008). It would be a long and expensive process to upgrade all passive crossings in Australia to active crossings or grade separated junctions (under/over passes).

A report from the Australasian Centre for Rail Innovation (ACRI) by White, Baldock, Woolley, Stokes, Royals and Sommariva (2015b) discussed less expensive, 'passive' solutions to improve train conspicuity at level crossings at night. One solution was the use of retro-reflective screens on the far side of the crossing to approaching drivers that reflect vehicle headlights. A passing train would intermittently obscure the retro-reflective surface, thereby alerting the driver to its presence through a strobing effect with the reflected headlights visible between carriages. This countermeasure may improve safety at level crossings at night and would not require an additional electricity supply or impede the function of trains or the existing infrastructure.

The present study evaluated the effectiveness of a prototype retro-reflective screen for improving the detection by motorists of freight trains at unsignalised level crossings at night. High quality videos of trains passing through a level crossing from the perspective of a vehicle on the approaching road were created. Day and night videos were created, with the night videos featuring both high and low beam vehicle headlights, and both the screen in place and absent. These videos were used in a reaction time experiment with a sample of drivers. The aim was to determine whether drivers react to trains at night faster when the screen is in place compared to when it is absent, thus demonstrating that it increases train visibility.

Methods

Participants

Participants were a convenience sample recruited through flyers posted around the University of Adelaide, as well as an email sent to undergraduate engineering students. They were required to have a full Australian (or equivalent international) driver licence in order to possess a basic level of driving experience and competency. They also had to be over 18 years of age and speak fluent English.

The sample consisted of 29 participants, with 12 (41.4%) males and 17 (58.6%) females. They ranged in age from 21 to 68 (mean=34.9 years, *SD*=15.2). Fourteen (48.3%) were full-time students, eighteen (62.1%) were working (12 full-time, five part-time, one casual) and two (6.9%) were retired. The highest education levels they had completed were: some high school = two (6.9%) participants, year 12 = twelve (41.4%), technical certificate = one (3.4%), diploma = two (6.9%), bachelor degree = four (13.8%), post graduate diploma = one (3.4%), post graduate degree = one (3.4%), four (13.8%) honours degree = four (13.8%), and master's degree = one (3.4%) (highest education not recorded for one participant). Thirteen (44.8%) were not born in Australian (three from China, two from India, two from England, and one each from South Africa, Germany, Iran, Hong Kong, Vietnam and Scotland), with their mean years in Australia being 15.3 (*SD*=12.0).

Materials

The retro-reflective screen

The prototype (1,230mm high by 200mm wide) was made of diamond-grade material (to maximise illumination by headlights). It was attached to the back of a Stop/Give way sign on the opposite side of the railway line from where it would be viewed (see Figure 1). It was attached for the experiment using cable ties and gaffer tape, ensuing it could be removed easily once the collection of video footage had been completed.

The screen was applied to a railway site at Mile End, South Australia and pilot-tested at night-time. The following were assessed:

- whether the screen suitably reflected headlights,
- distances at which it could be seen with headlights,
- whether the size of the screen was suitable,
- optimal height for it to be attached,
- whether the temporary methods to secure it were suitable, and
- whether it provided the 'strobing' effect between the carriages of a passing train.

Production of videos

Following pilot-testing, a suitable location for recording video footage of freight trains passing through a level crossing with the screen was identified at Callington, South Australia with the assistance of the Australian Rail Track Corporation (ARTC). Importantly, this crossing was unsignalised, had a straight approaching unsealed road, had nothing obscuring the crossing from the perspective of an approaching motorist, and had no artificial lighting.

Researchers attended the site during the day and secured the screen to the back of a Stop Sign. Train schedules were provided by the ARTC in order to anticipate freight trains

Figure 1. Retro-reflective screen applied to the back of a stop sign

passing through the crossing. A car was parked 200 metres from the crossing on the approaching road in a lateral position consistent with the travel path of a car driving on the road. A high definition (4K) video camera (Sony HXR-NX80) was set up in front of the car (perspective of the driver) with the zoom set at 40%, which was subjectively determined to be consistent with a person's primary field of vision. Video footage of a passing train was recorded for the day condition. Next, footage of a passing train was recorded at night with the screen in place and the high beam headlights of the parked vehicle on and then the low beams on. After the train had passed, the screen was removed. The researchers waited for another train and again recorded footage with both high and then low beams. Removing the screen between trains meant that the train in the night videos with the screen was different from the train in the night videos without the screen.

Later viewing of the night footage with low beams and the screen in place revealed that it was inadequate for the experiment. The researchers therefore had to return to the site some weeks later to re-film this footage with a different train. The exact same procedure was used, except only footage at night with low beams and the screen was recorded.

Reaction time experimental materials

A computer program was developed to present train videos to participants for the reaction time experiment. Each video commenced with footage of the crossing with no train present. Participants were expected to react when the train passing through the crossing appeared. The lead-in time prior to the appearance of the train varied between 6, 12 and 18 seconds. This meant that the time passing before the appearance of the train in each video was unpredictable. The lead-in time for the day video was always 12 seconds. Footage of the train passing through the crossing lasted for 20 seconds.

The five individual videos in the program were:

- DDD: day, measured baseline reaction time with optimal light.
- NHU: night, high beams, untreated (no screen).
- NHT: night, high beams, treated (screen) – still from video provided in Figure 2.
- NLU: night, low beams, untreated.
- NLT: night, low beams, treated.

Figure 2. Still from NHT video showing a train passing through the crossing (note the retro-reflective screen on right side of road, which strobed between carriages)

Five rounds of the five videos were presented to each participant. The DDD video was shown first in each of the five rounds. The order of the night videos was varied between participants and between rounds. This was done to control for order effects and the five-round design allowed for practice effects to be examined. The participant was required to react when the train appeared by pressing any key on a keyboard, and then pressing a key again to move onto the next video (or the end screen if it was the final video). Reaction times to each video were recorded by the program. It should be noted that the DDD video showed the front of the train passing through the intersection. However, the night videos did not show the front of the train, as this would have had obvious lights on it. Instead, the lead-in time with no train would end and it would cut straight to the carriages already passing through the crossing. This replicated the situation in which a vehicle would approach the crossing when the front of the train had already passed but the carriages were still passing through.

Participants could incorrectly react to a video in two ways. Firstly, they might press a button before the train had appeared (i.e., during lead-in time), either accidentally or because they incorrectly thought they had seen a train. In such cases, the program would make a loud 'beep' sound, the video would continue (allowing them to correctly react when the train did appear), and an 'error' was recorded in a separate field in the data. Secondly, the 20 seconds in which the train was shown passing at the end of a video might conclude without the participant pressing a key. In such cases, the video would freeze (demonstrating its conclusion), the researcher would press a key on the laptop to skip to the next video (or the end screen), and a reaction time of 20 seconds was recorded. These 20 second reaction times were later identified as 'misses'.

To present the videos, a laptop computer was attached to a 65-inch high-definition Liquid Crystal Display (LCD) television via a High-definition Multimedia Interface (HDMI) cable. Participants sat one and a half metres from the screen and used a keyboard to respond. The experiment was conducted in a dark room to simulate night conditions.

Procedure

Participants attended a single session at the University of Adelaide. They were encouraged to bring any corrective eyewear that they require for normal driving. Upon arrival, an information sheet and a consent form were provided to them. They read both forms and signed the consent form. The information sheet informed them that they could withdraw from the study at any stage (until publication of the results) and that their data would remain confidential. It took approximately ten minutes for a participant to view and react to all videos. Participants were not informed about the retro-reflective treatment prior to taking part in the study but it was discussed with them following completion.

The following instructions were given before participants started the experiment:

"You are going to see a number of videos of a crossing between a railway line and a road. There will be both daytime and night-time videos. At first there will be no train in the crossing, but at some stage during the videos a train will suddenly be passing through. As soon as you see a train you need to press any key on the keyboard. It's a reaction time test, so you need to press the button as fast as you can when you see the train. If you press a button accidentally or you think you see a train and press a button, but the train has not appeared yet, the program will beep. That's okay, just keep going until you do see a train".

The study was conducted according to the National Health and Medical Research Council (NHMRC) National Statement on Ethical Conduct in Human Research 2007 (updated 2018) and was approved by the Human Research Ethics Committee at the University of Adelaide (approval number H-2018-037). Following completion of the experiment, participants and their data were only identified using an assigned chronological number. In gratitude for their time, participants were entered into a draw for an iPad.

Multivariate Analysis of Variance (ANOVA), with post-hoc pairwise comparisons, was used to examine reaction times to the night videos (NHU, NHT, NLU, NLT) and determine whether the reaction times were affected by the treatment, and whether this was affected by the headlight setting on the vehicle. For all analyses, an alpha level of 0.05 was used to determine statistical significance.

Results

The extent of 'errors' (participant reacted before train was present) and 'misses' (participant did not react to train) were examined. The number of errors was small, with 31 across all participants, videos and rounds (out of 725 total videos shown). The 31 errors were made by 17 different participants. Sixteen participants made between one and three errors, but one participant made six. Only three errors were made in day videos, with 28 in night videos. This was likely due to trains being more difficult to see in night videos. There was no pattern in the experimental round in which they occurred (4 in Round 1, 11 in Round 2, 7 in Round 3, 5 in Round 4 and 5 in Round 5).

The number of 'misses' was also small, with 13 across 725 total videos. However, all 13 were made in NLT videos. They were made by seven different participants. Five participants only made one miss, and all of these were in the first round. However, one participant made misses in rounds 1, 2 and 5 and another made a miss in every round. The tendency to make fewer misses in later rounds was likely due to practice effects, with participants becoming accustomed to the retro-reflective screen and understanding that the strobing effect meant a train was present. 'Misses' were recorded in the data as a reaction time of 20 seconds. This meant that, although few in number, they could increase the mean reaction time in NLT videos. Consequently, misses were removed from the data and not included in any analyses.

Mean reaction times to the day video across five rounds and to all night videos across five rounds were calculated for each participant. The mean day reaction time for all participants of 0.516 seconds (*SD*=0.086) was significantly faster than the mean night reaction time of 1.011 seconds (*SD*=0.305), according to a paired-samples *t*-test ($t(28)=9.7$, $p<.001$). This indicates that, not surprisingly, drivers react to trains faster in daylight compared to night-time conditions.

Mean reaction times to the night videos separately across five rounds were: NHU=0.923 seconds (*SD*=0.175), NHT=0.692 seconds (*SD*=0.080), NLU=0.675 seconds (*SD*=0.150), and NLT=1.760 seconds (*SD*=1.135). Figure 3 presents means and 95% confidence intervals. Means for NHT and NLU were similar and had overlapping confidence intervals. While the mean for NHU was higher (longer reaction time) than both NHT and NLU, the mean for NLT was much higher than all other means (confidence intervals for NHU and NLT did not overlap with any others). Mean reaction times were analysed using a repeated-measures ANOVA with two within-participants factors of vehicle headlight (high vs low beam) and presence of the retro-reflective screen (untreated vs treated). Main effects due to headlight ($F(1,27)=14.29$, $p=0.001$, $\eta^2=0.346$) and the screen ($F(1,27)=16.28$, $p<0.001$, $\eta^2=0.376$) and the interaction between these ($F(1,27)=38.80$, $p<0.001$, $\eta^2=0.590$) were statistically significant.

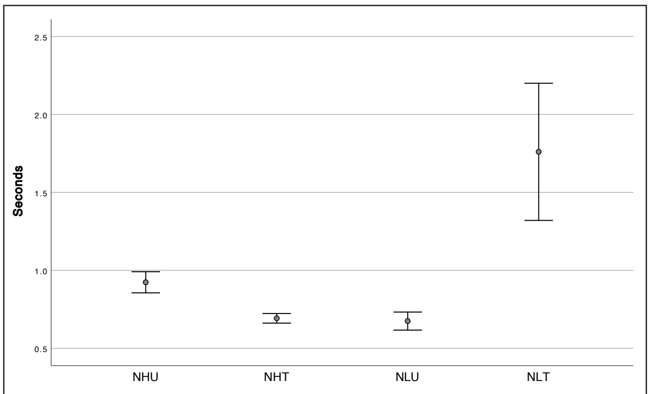

Figure 3. Mean reaction times and 95% confidence intervals across five experimental rounds

This suggests that each variable had a main effect on variance in reaction times (accounting for 35% and 38% of variance respectively), but by examining Figure 3 it is clear that the interaction effects (59% of variance) of the two variables mediate the direction (either shorter or longer reaction time) of each main effect. Consistent with expectations, the screen improved reaction times when high beam headlights were used (NHU vs NHT), but, contrary to expectations, led to a large increase in reaction times (slower reactions) when low beams were used (NLT vs NLU). Another unexpected result was that the NHT video, expected to be the easiest video in which to detect the train, did not differ from the NLU video, expected to be the most difficult video in which to detect the train. Pairwise comparisons showed that all means significantly differed from each other at $p<0.008$ (adjusted to a more conservative alpha level to account for multiple comparisons), except for NHT and NLU.

To examine the degree of practice effects in the experiment, repeated-measures ANOVA tests were used to determine whether the mean reaction times differed between experimental rounds for each video type separately (see Table 1). ANOVA models for NHU and NLT were statically significant. Pairwise comparisons showed that, for both NHU and NLT, Round 1 significantly differed from all other rounds at $p<0.05$. There were no significant differences between any of the later rounds. This indicates that participants improved from Round 1 to consistent reaction times in Rounds 2, 3, 4 and 5 and, therefore, that there were practice effects between Rounds 1 and 2.

Consequently, the final analysis examined mean reaction times to the night videos separately across the later four rounds (Round 1 excluded). The purpose was to examine reaction time results after participants had practised the four videos and their reactions had become consistent. Mean reaction times across Rounds 2, 3, 4 and 5 were: NHU=0.855 seconds (*SD*=0.156), NHT=0.684 seconds (*SD*=0.088), NLU=0.673 seconds (*SD*=0.177), and NLT=1.148 seconds (*SD*=0.608). Figure 4 presents means and 95%CIs. While the mean reaction times for NHU and

Table 1. Mean reaction times (in seconds) by experimental round and video type

Video	Round 1	Round 2	Round 3	Round 4	Round 5	Repeated-measures ANOVA
NHU	1.203	0.873	0.889	0.813	0.871	*$F(4,114)=9.95$, $p<0.001$, partial $\eta^2=0.262$
NHT	0.739	0.694	0.701	0.677	0.686	$F(4,114)=1.66$, $p=0.186$, partial $\eta^2=0.056$
NLU	0.771	0.669	0.761	0.633	0.647	$F(4,108)=1.43$, $p=0.248$, partial $\eta^2=0.050$
NLT	4.938	1.409	1.136	1.038	1.040	*$F(4,84)=10.10$, $p=0.004$, partial $\eta^2=0.325$

*Repeated-measures ANOVA model statistically significant at $p < 0.05$

NLT were slightly shorter (faster reactions) than when all five rounds were included, the same pattern of results was evident (NHT and NLU with similar means, NHU slightly slower, and NLT considerably slower). There was, however, a small overlap this time between the confidence intervals for NHU and NLT.

Mean reaction times were again analysed using a repeated-measures ANOVA with two within-participants factors of vehicle headlight and presence of the screen. Main effects due to headlight ($F(1,27)=4.75$, $p=0.038$, $\eta^2=0.150$) and the screen ($F(1,27)=9.24$, $p=0.005$, $\eta^2=0.255$) and the interaction between these ($F(1,27)=44.03$, $p<0.001$, $\eta^2=0.620$) were statistically significant. Pairwise comparisons showed that all means significantly differed from each other, except for NHT and NLU and NHU and NLT, at $p<0.008$ (more conservative alpha level for multiple comparisons). These results substantiate the earlier results in which all five rounds were included. It should be acknowledged that, while results excluding practice were interesting, they would not reflect real-world conditions, in which, if a screen was applied to an intersection, many drivers would travel through it for the first time and would not have prior understanding of its purpose.

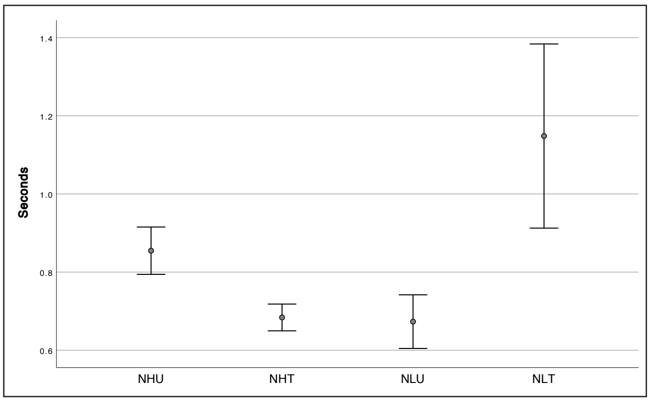

Figure 4. Mean reaction times and 95%CIs across Rounds 2, 3, 4 and 5

Discussion

The intention of this project was to evaluate the effectiveness of a prototype retro-reflective screen for improving the detection by motorists of freight trains travelling through unsignalised level crossings at night. A screen was pilot-tested, with the desired retro-reflective lighting effects achieved. It was then applied to a level crossing in the manner in which it would be used in real-world applications. Videos of passing freight trains from the perspective of an approaching vehicle were recorded and used in a reaction time experiment. The aim was to determine whether drivers react to trains at night faster when the screen is in place compared to when it is absent, thus demonstrating that it increases train visibility and potentially improves safety. Overall, the results were mixed in relation to the effectiveness of the screen. When the approaching vehicle was using high beam headlights, the screen led to shorter reaction times, which suggests it improved visibility of the train. The opposite was found for low beams. The screen led to longer reaction times, which suggests it reduced visibility of the train or possibly confused drivers. Furthermore, all occasions in which the participant failed to detect the train occurred when low beams were used, and the screen was present.

The effectiveness of the screen with high beams is a positive finding. The strobing effect appeared to provide a highly visible, dynamic cue for drivers to react to and it reduced the time for drivers to process the presence of a train. In a real-world situation, this improvement in reaction time (difference of 0.231 of a second between means for NHU and NHT) equates to a reduced stopping distance of 6.4 metres for a light vehicle travelling at 100 km/h on an unsealed road. This improvement is small but positive (note, however, that a vehicle should not be travelling through the crossing at 100 km/h, unless they have deliberately disobeyed the Give Way or Stop sign or failed to see it).

Train carriages, although dark, were visible in both night videos with high beams, which suggests that using high beams is the safest way to approach unsignalised level crossings in rural areas. It is common for drivers to use high beams in rural Australian areas at night. However, it cannot be expected that all drivers will use high beams when approaching a rural level crossing. This leads to the second result, which does not simply suggest that the screen is ineffective with low beams but that it can have a detrimental effect. It is unclear exactly why this result occurred, although there are several likely explanations. It is potentially due, at least in part, to methodological limitations. As mentioned in the methods section, there were different trains in the two low beam videos. The main noticeable difference was that, while the carriages were not visible in either, as it is very dark, there is a small light on the side of the train in the video without the screen (NLU). This light shows almost exactly as the train appears following the lead-in time and moves horizontally with the train. It is possible that the participants reacted to this cue. In comparison, the train in the video with the screen (NLT) has no such lights and participants only have the dully strobing screen (as it is very dark compared to the high beam videos) to react to.

Participants reacted to the low beam, untreated video (NLU) as quickly (see Figure 3 means) as the high beam, treatment video (NHT – in which the screen strobed brightly, and carriages were visible). This suggests that the lateral movement of the small light was clearly identifiable as train movement. In comparison, the strobing screen in the NLT video did not possess lateral movement. Ideally, future research would ensure that trains in all videos were equivalent in terms of lights and retro-reflective material on the sides of carriages. This may in practice prove difficult with videos of real trains (i.e., getting several trains that look the same could be problematic, especially given the large variation in the carriages they pull and the infrequency of trains in rural areas).

The large variance in reaction times for the NLT video (see Figure 3 confidence intervals) is consistent with confusion by the participants about whether they should react to the strobing screen. Also, there were not many 'misses' (participant did not react at all to train) during the experiment, but *all* were in the NLT video. These were removed from the analyses and so would not have affected the results. However, the misses in that condition (NLT) do suggest that participants were confused about whether the screen indicated a train. There were practice effects for this video (participants improved from Round 1 to 2 and most misses occurred in Round 1). However, even when Round 1 data were removed from analyses, reaction times to this video were still significantly longer than the other videos.

Confusion about whether the screen indicated a train could also have been due to the instructions given by the researcher. Participants were instructed to press a button as fast as they could when they saw a train. Therefore, they were looking for trains, not a strobing light. They may have noticed the strobing screen but decided not to let that distract them from spotting the train. Consideration had been given to different instructions. One option was "press the button when you see something you should brake for". However, the crossing featured a Stop Sign and so participants could have pressed the button immediately in response to that. Even if this issue could be addressed, participants may not have identified the strobing light as something requiring a braking response. Indeed, they may have falsely imagined it to be a distracting visual feature built into the experimental design.

The detrimental effect of the screen in low beam conditions is also likely to be accounted for by the operative lighting distance of low beam headlights (typically 40-50 metres). The distance of 200 metres between car and crossing in this experiment was likely too far for the retro-reflectiveness of the screen to be fully effective.

Despite the methodological limitations, it might truly be the case that the screen confuses or distracts the driver, and this may occur in real-world conditions. The longer reaction time (a difference of 1.085 seconds between means for NLU and NLT) equates to an increased stopping distance of 30.1 metres for a light vehicle traveling at 100 km/h on an unsealed road. This could compromise safety (again, however, a vehicle should not be travelling through the crossing at 100 km/h, unless they have deliberately disobeyed the Give Way or Stop sign or failed to see it). Further experimental testing of the screen would be required, ideally with all present methodological limitations addressed, to determine whether the results in low beam conditions persist. If this continues to be the case, efforts to improve conspicuity and safety at passive level crossings at night should be directed towards other viable countermeasures, if it is not possible to upgrade them to active crossings or grade separated junctions.

Other Potential Countermeasures

As mentioned earlier, it is possible that the lateral movement of lights on the side of the train in the NLU video worked as an effective train indicator. It seemed less confusing than the retro-reflective screen, which was strobing but stationary. This suggests that the best countermeasure to increase the conspicuity of freight trains already passing through an intersection at night when a vehicle approaches would be to have lights and/or retro-reflective material applied to freight trains. To achieve optimal safety results, this countermeasure would require that lights and/or retro-reflective material would be applied uniformly across the entirety of the sides of individual trains and uniformly across all trains in the industry. However, if the improved reaction times in the NLU condition in this study occurred because of a single small light, it is possible that even sub-optimal application of retro-reflective material to trains would be beneficial.

Rail Industry Safety and Standards Board (RISSB) Rolling Stock Standard AS7531:2015 Section 11 provides recommendations for the installation of retro-reflective strips to the sides of trains. The recommendations relate to mounting of the strips, spacing, materials, dimensions, and colour. Five of these are recommended and five are mandatory. The application of 'reflective delineators' according to this standard would be expected to markedly improve train conspicuity at night for approaching motorists. It should be noted that this would be most beneficial for freight trains. Applying reflective material to passenger trains may prove useful as an additional safety measure but would likely not be as beneficial because passenger train carriages have illuminated windows that provide lateral light movement.

The reduction of speed limits on approaches to level crossings is widely recognised as an important safety measure (White, Baldock, Woolley, Stokes, Royals and Sommariva, 2015a; Edquist, Stephan, Wigglesworth and Lenne, 2009), as hazard detection capacity declines at higher travelling speeds. In particular, speed limits at approaches in rural areas could be dropped from open 110 km/h and 100 km/h limits to 80 km/h. This would be relatively inexpensive to implement. Where level crossings are controlled by Stop signs, speed limits could be sequentially reduced down to a very low speed in the immediate vicinity (White et al., 2015b).

As well as the retro-reflective screen evaluated in the present report, the ACRI report by White et al. (2015b) also mentioned the following countermeasures:

- Local area traffic management interventions (horizontal/vertical deflections) force vehicles to reduce speed but may not be easily implemented on unsealed roads.
- Elimination of Give Way signs in favour of Stop signs, as they indicate that the driver needs to stop rather than continue through the crossing if a train is not detected.
- Illumination of the crossing, although this could be cost prohibitive to implement at a large number of level crossings.

Limitations

This study had several limitations. Firstly, the design meant that the experiment was measuring whether participants were able to perceive the train in conditions in which they were *actively looking for one*, but was not necessarily generalisable to all circumstances, including less attentive motorists in real-world situations. Secondly, the footage was replicating the point of view of a stationary observer 200m from the crossing. In reality, the observer would have been in a moving vehicle. An alternative approach would have involved footage from a vehicle travelling toward the train, and assessment of the distance from the crossing at which the train was detected. This, however, would have been difficult to organise, requiring exact timing of the arrival of the train, and taken much longer to collect footage, as a larger number of trains would have been required. Finally, the study could not demonstrate the durability of the prototype and, therefore, its ability to retain long-term retro-reflective effectiveness. That would require further testing in a separate field trial.

Conclusions

Given the detrimental effect of the screen on reaction times and detection rates in low beam conditions, the overall conclusion is that further experimental testing would be required to demonstrate the conclusive feasibility of retro-reflective treatment of level crossings. Future research should seek to address the current methodological limitations. It would not currently be prudent to recommend a larger field trial of the screen, particularly in real-world conditions with actual vehicles and drivers.

Acknowledgements

The authors would like to thank staff at the South Australian office of Australian Rail Track Corporation (Gary Templeton, Phillip Campbell, and Kleo Ioannidis) for their assistance with training, with the provision of train schedules, and with facilitating safe access to level crossings for collection of the footage used in this experiment. The authors would also like to thank Craig Kloeden, for developing the reaction time experimental program, and Martin Elsegood for helping to record video footage of trains passing through the level crossing at Callington, both from the Centre for Automotive Safety Research.

Funding

This work was funded by the Australasian Centre for Rail Innovation. Representatives of the funding organisation were involved in the study design and the decision to submit the paper for publication. They were not involved in the design, production or pilot-testing of the retro-reflective screen, the collection of data, the manuscript preparation, or the analysis and interpretation of the data. The Centre for Automotive Safety Research at the University of Adelaide is supported by the South Australian Department of Planning, Transport and Infrastructure.

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Road Safety Data, Research & Evaluation Methods

Investigation of Injury patterns in Heavy-duty Single Vehicle crashes based on real-world accident data in Tamilnadu, India

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This peer-reviewed paper was first submitted as an Extended Abstract and an Oral Presentation was recommended by two reviewers at the 2021 Australasian Road Safety Conference (ARSC2021) to be held in Melbourne, Australia in September. The two Reviewers also recommended that the Extended Abstract be expanded into a 'Full Paper' and undergo further peer-review as a journal submission by three independent experts in the field. The Extended Abstract will be published in the ARSC2019 Proceedings with a link guiding readers to this 'Full Paper' version which is being reproduced here with the kind permission of the authors and will only be available in this edition of the JRS.

Key Findings

- 4704 Heavy-duty single-vehicle crashes occurred in Tamilnadu state, India from Jan 2013 to Dec 2018;
- Examined the relationship between crash, driver, road, environment, injury characteristics with injury severity;
- Heavy-duty vehicle drivers involved in fatal crashes were most likely male adults (25-64 years) with valid license;
- Fatal crashes were more common in northern and southern regions of Tamilnadu state, India;
- The majority of drivers hospitalised in the fatal heavy-duty single-vehicle crash sustained wounds/cut and severe coma.
- Nearly 30% of drivers sustained multiple injuries, head injuries, and hand injuries in heavy-duty single-vehicle fatal crashes.

Abstract

According to the reports of NITI (National Institute of Transforming India) Aayog Freight 2018, Road freight is the prime mode (59%) of transport in India with the highest per ton-mile cost than rail or water freight (NITI Aayog, 2018). This road freight usually uses heavy-duty vehicles to transmit voluminous goods and services to the destination in time. Due to this, the heavy-duty vehicle population increased on the Indian roads. Heavy-duty vehicle crashes cause a substantial economic burden to the nation and result in more severity to the involved because of differences in weight, speed, and size. Among heavy-duty vehicle crashes, a significant proportion of crashes are heavy-duty single-vehicle crashes. Single-vehicle crashes are those crashes where the vehicle drivers either involve in self-skidding or hit a stationary object (like a tree). The purpose of this study is to investigate the injury pattern in heavy-duty single-vehicle crashes.

For this study, the data is extracted from the RADMS (Road Accident Database Management System) database and linked with hospital data. This data includes demographic information, road, environmental and injury characteristics. Later, descriptive statistics performed on the dataset to analyse all heavy-duty single-vehicle crashes between January 2013 and December 2018. Overall, 4704 single heavy-duty vehicle crashes occurred during this period, among which 1244 were fatal crashes. Results show that male drivers aged 26 to 64 years old suffered more fatalities (88%), followed by the 18-25 age group (8%). Examination of injury information found that heavy-duty vehicle drivers mostly sustained multiple injuries (9.05%), head injuries (5.05%), followed by leg injuries (4.29%). The results showed that specific road and environmental factors increase the chance of fatal crashes among heavy-duty vehicle drivers. Furthermore, the proposed study gives insight into the injury characteristics and key contributing factors causing heavy-duty single-vehicle crashes. Finally, this study provides appropriate countermeasures and techniques that can mitigate heavy-duty single-vehicle collisions.

Keywords

Heavy-duty vehicles, Injury pattern, Injury severity, Hospital data, Single-vehicle crashes

Introduction

Road Traffic Injuries (RTI's) are threatening the world, with 1.35 million deaths every year. RTI's are the leading cause of death among the 5-29 years age-group (World Health Organisation, 2018). Low- and middle-income countries (LMIC) constitute around 93% of world fatalities though having only 60% of the world's vehicle population. India, an LMIC and second-most populous country with more than 1.3 billion inhabitants, contributes 11% to the world's road traffic deaths (World Health Organisation, 2018). In India, Tamilnadu state has the highest number of crashes (63,920), followed by Maharashtra (51,397), Uttar Pradesh (42,560), Karnataka (41,707), and Kerala (40,181) (Ministry of Road Transport and Highways (MORTH), 2018). In terms of fatalities, Uttar Pradesh has the highest number of deaths (22,256), followed by Maharashtra (13,261), Tamilnadu (12,216), Karnataka (10,609), and Madhya Pradesh (10,706) (MoRTH, 2018). The above statistics clearly show that Tamilnadu is among the topmost states with the highest numbers of crashes and fatalities.

A heavy-duty vehicle is a vehicle having more than 3.5 tonnes (trucks) or a passenger vehicle having more than eight seats (i.e., buses and coaches) (European Commission, 2014). Heavy-duty vehicles require reliable infrastructure for an effective flow of commodities to shippers and carriers throughout road freight (Uddin and Huynh, 2017). Its safety is paramount vital for the smooth flow of goods and services in any developing nation. Heavy-duty vehicle crashes, among various crashes, are important to mitigate because of their nature to cause more severity to the people involved and damage it causes to infrastructure (Zou et al., 2017). In India, 1,20,970 heavy-duty vehicle crashes resulted in 1,25,097 injuries and 48,745 fatalities (MoRTH, 2018). Tamilnadu is an urbanised and industrialised state with the highest number of accidents in India. In this state, nearly 65% of road freight is through heavy-duty vehicles (Motor vehicle acts-administration, 2018-19)

In general, dichotomising single-vehicle and multiple-vehicle crashes were significant for proposing effective countermeasures (Chen and Chen 2011; Dong et al., 2018; Geedipally and Lord, 2010; Lord et al.,2005; Wu et al., 2014). There is a significant difference between mechanisms of single-vehicle and multi-vehicle crashes (Dong et al., 2018). Moreover, there is a substantial difference in the factors causing injury severity to the drivers involved in heavy-duty single-vehicle crashes (Zou et al., 2017). Researchers in the past studied the injury severity of heavy-duty vehicle crashes (Azimi et al., 2020, Behnood and Mannering, 2019; Islam and Hernandez, 2013a; Osman et al., 2016; Uddin and Huynh, 2017, 2018; Zhu and Srinivasan, 2011). Regardless of the critical importance of heavy-duty single-vehicle crashes, very few in literature focused on heavy-duty single-vehicle crashes (Naik et al., 2016; Zou et al., 2017, Ehsan et al., 2020). Moreover, these studies were mostly from developed nations. Their outcomes do not apply to developing countries like India because of differences in roadway conditions, roadside environments, policies and practices, and more prominent driver behaviour (Sivasankaran and Balasubramanian, 2020).

This study investigates injury patterns among heavy-duty single-vehicle crashes to fill the literature gap, particularly in developing countries. This study helps policymakers in developing effective countermeasures for such crashes. As per the author's knowledge, this study may be the first of its kind in Tamilnadu state, India. Descriptive statistics are conducted on the data to know the frequencies and percentage of variables causing fatal and non-fatal crashes. Logistic regression is applied to compare the contributing factors driving fatal and non-fatal crashes in the study.

Research Objective

MoRTH 2018 report shows that there were about 48,745 fatalities in heavy-duty vehicle crashes in the country. It is an increase of about 1.2% than the previous year. Tamilnadu is one of the country's leading states in road fatalities, followed by Maharastra and Uttar Pradesh. Among heavy-duty vehicle crashes, a significant proportion of crashes were single-vehicle crashes. After signing the Brazilia declaration in 2015 (i.e., 2nd Global High-Level Conference on Road Safety by World Health Organisation (WHO)), tremendous efforts are ongoing to tackle the rising burden of crashes in the country. These efforts are not enough to mitigate the heavy-duty vehicle crashes, as highlighted in the MoRTH latest reports. To investigate the factors that contribute to such collisions, authors explored the six-year data to know the epidemiology of heavy-duty single-vehicle drivers morbidity and mortality in the Tamilnadu state

The present study examined the severity classification among injured or deceased drivers in heavy-duty single-vehicle crashes. This study's objective is to investigate some of the questions regarding Heavy-duty Single-vehicle crashes. The research questions that guided the study include

1. What is the epidemiology of the heavy-duty single-vehicle crashes in Tamilnadu regarding location, persons, time?
2. What is the collision nature and driver-errors, which contributed to the fatalities in heavy-duty single-vehicle crashes?

3. What are the injury nature and injury mechanism of heavy-duty vehicle drivers who were involved in fatal crashes?

Additionally, the present study explores the causes and consequences of heavy-duty single-vehicle fatal and non-fatal crashes.

Methodology

Data Preparation

The current study used the RADMS dataset provided by the state traffic planning cell (STPC) Tamilnadu. RADMS data is well used in the past to investigate various crashes and their related characteristics (Sivasankaran and Balasubramanian, 2020 a,b,c,d, Balasubramanian and Sivasankaran, 2020). In India, Tamilnadu is a manufacturing hub contributing more than one-third to its gross domestic product (GDP) (Alagarsamy and Srinivasan, 2013). Industries usually depend on heavy-duty vehicle for their road freight. With the proportion of this freight increase, there is an increase in heavy-duty vehicle crashes in Tamilnadu.

To study this objective, the authors extracted all heavy-duty vehicle crash data from the RADMS database from January 2013 to December 2018. The below requisites used to extract single heavy-duty vehicle crashes data from the RADMS Database.

•Colliding Vehicle type = ”Bus”, ”Truck”, ”Tractor”, ”Heavy articulated vehicle/trolley and Crash type = ”Single- vehicle.”

Crash data for six years comprises 6128 heavy-duty single-vehicle crashes in 3 separate files. The first file consists of crash details: time of the day, location, crash severity, crash type, weather condition, road condition, and few built environments. The second file includes vehicle data: vehicle type, vehicle make, vehicle model, vehicle year and few vehicle characteristics. Finally, the third file comprises driver data: driver age, driver gender, driver license status, mobile use, seat belt usage and alcohol/drug usage. All these files contain a unique identification number. This unique identification number in these datasets used to link with hospital data. This hospital data has injury severity, nature of the injury, injury type, hospital mode and hospital delay. In this study, upon considering only fatal, grievous and simple injury (hospitalised) crash cases, there were 4704 single heavy-duty vehicle crashes. As per Indian medical practice,

- • Fatality is when a road user involved in a crash and killed within 30 days of the crash
- • Grievous injury is when a road user stayed in the hospital with injury for 24hrs or more and
- • Simple injury is when a road user stayed in the hospital with injury for less than 24hrs

Descriptive and Logistic Regression Analyses

Descriptive Statistical analysis is conducted on the comprehensive dataset to know the frequency and percentage of variables causing fatal and non-fatal crashes. The variables in the dataset classified as driver characteristics (age, gender, license type, mobile use, seat belt use and alcohol/drug use), crash characteristics (day of the week, number of lanes, traffic control, junction type, central divider, and light, weather and road conditions), and injury patterns and severity characteristics (injury nature, injury descriptors, hospitalisation delay, hospitalisation

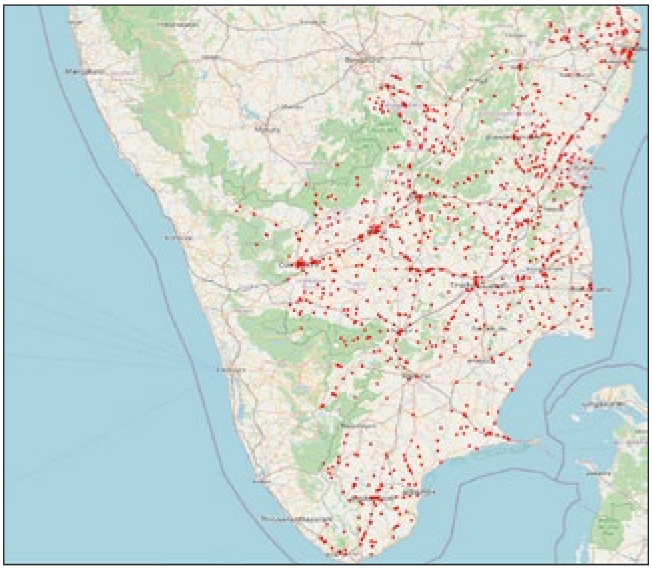

Figure 1: Occurrence of heavy-duty single-vehicle fatal crashes in Tamilnadu state, India during 2013-2018

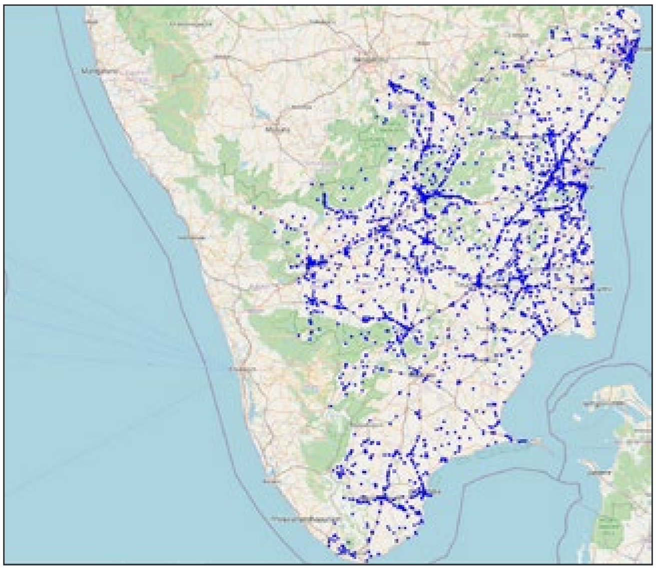

Figure 2: Occurrence of heavy-duty single-vehicle non-fatal crashes in Tamilnadu state, India during 2013-2018.

Table 1. Heavy-duty single-vehicle crashes classified based on Demographics

		Fatal	Non-Fatal	Total
		Frequency(%)	Frequency(%)	Frequency(%)
Driver Gender	Male	1244(100)	3455(99.9)	4699(99.9)
	Female	0(0.0)	5(0.1)	5(0.1)
Driver Age	<18	38(3.1)	131(3.8)	169(3.6)
	>64	4(0.3)	13(0.4)	17(0.4)
	18-24	106(8.5)	197(5.7)	303(6.4)
	25-64	1096(88.1)	3119(90.1)	4215(89.6)
Valid License	No	317(25.5)	667(19.3)	984(20.9)
	Yes	927(74.5)	2793(80.7)	3720(79.1)
Seatbelt Use	No	1232(99.03)	3428(99.1)	4660(99.06)
	Yes	12(0.96)	32(0.9)	44(0.94)
Alcohol/Drug use	No	1244(100.0)	3452(99.8)	4696(99.8)
	Yes	0(0.0)	8(0.2)	8(0.2)

mode). A logistic regression model is used to compute the odds ratio of explanatory variables with the dependent variable, i.e., Fatal. R, an open-source statistical package, was used in this study to code and analyse the data in datasets. Statistical significance- Alpha(α) value 0.05 used for all analyses.

Table 2. Heavy-duty Single vehicle driver's injury severities classified based on body regions

	Fatal	Non-Fatal
	Frequency (%)	Frequency (%)
Back Injury	1(0.1)	3(0.1)
Buttocks Injury	0(0.0)	2(0.1)
Chest Injury	15(1.2)	14(0.4)
Face Injury	13(1.0)	57(1.6)
Hand Injury	33(2.7)	101(2.9)
Head Injury	159(12.8)	79(2.3)
Hip Injury	12(1.0)	28(0.8)
Knee Injury	9(0.7)	45(1.3)
Leg Injury	13(1.0)	189(5.5)
Multiple Injuries	173(13.9)	253(7.3)
Neck Injury	4(0.3)	22(0.6)
Not Applicable	809(65.0)	2643(76.4)
Shoulder Injury	3(0.2)	24(0.7)

Results

The authors used the Police-reported locations to map heavy-duty single-vehicle fatal and non-fatal crashes in Tamilnadu state, India, from January 2013 to December 2018, as shown in Figure 1 and Figure 2. An open-source software, python with a folium package, was used to map crash details.

Injury Analysis of Heavy-duty single-vehicle drivers

Heavy-Duty single-vehicle drivers Demographics and Injury Severity

Descriptive statistical examination on driver's demographics showed that drivers involved in all fatal cases were male. Only 0.1% of female drivers were involved in non-fatal crashes. Drivers in the age group of 25-64 contribute nearly 88% to all fatal crashes, followed by the 18-24 age group (8.5%). Almost 99% of drivers in fatal cases were not wearing a seat belt—such behaviour is identified commonly among drivers aged between 25 and 64 years. Only 0.2% of drivers who consumed alcohol/ drugs are involved in non-fatal cases.

Comparison of injured body regions and injury nature among fatal and non-fatal heavy-duty single vehicle:

Table 2. gives an overview of the driver's body regions injured in single heavy-duty vehicle crashes. Among fatal cases, 13.9% of drivers sustained multiple injuries, followed by 12.8% head injuries and 2.7% hand injuries. This trend differs slightly for non-fatal cases; drivers

Table 3. Single heavy-duty vehicle driver's injury severities based on the nature of injuries

	Fatal	Non-Fatal
	Frequency (%)	Frequency (%)
Abrasion	46(3.7)	256(7.4)
Chest Trauma	13(1.0)	7(0.2)
Contusion	31(2.5)	69(2.0)
Cranial Trauma	26(2.1)	7(0.2)
Fracture or Dislocation of Bone or Tooth	18(1.4)	28(0.8)
Not Injured	803(64.5)	2616(75.6)
Not Applicable	7(0.6)	11(0.3)
Permanent Disfigurement of Head or Face	55(4.4)	5(0.1)
Privation of Any Member or Joint	0(0.0)	2(0.1)
Severe Coma	85(6.8)	7(0.2)
Wounds/Cut	160(12.9)	452(13.1)

sustained 7.3% multiple injuries, 5.5% leg injuries, 2.9% hand injuries, and 2.3% head injuries. The injury pattern differs significantly for both fatal and non-fatal crashes among different body regions for heavy-duty single-vehicle drivers (Chi-square =321.436, p< 0.001).

Injury nature (refer to **Table 3**) of heavy-duty single-vehicle drivers differed significantly among fatal and non-fatal crashes (Chi-square=440.62, p<0.001). Regrading the injury nature among drivers, they commonly sustained wounds/cuts (13.01%), followed by abrasion (6.42%). Driver in fatal cases likely to suffer from wounds/cuts (12.9% vs 13.1%) and severe coma (6.8% vs 0.2%) compared to non-fatal crashes.

Table 4. Hospitalisation delay in single heavy-duty vehicle crashes severities

Hospitalisation Delay	Fatal	Non- Fatal
	Frequency (%)	Frequency (%)
Hospital More Than 2 Hours After Crash	14(1.1)	13(0.4)
Hospital Between 1 Hour And 2 Hours After Crash	108(8.7)	203(5.9)
Hospital Between 30 Minutes And 1 Hour After Crash	119(9.6)	290(8.4)
Hospital Within 30 Minutes After Crash	138(11.1)	355(10.3)
Not Hospitalised	853(68.6)	2583(74.7)
Unknown	12(1.0)	16(0.5)

Table 5. Hospitalisation mode in single heavy-duty vehicle crashes severities

	Fatal	Non- Fatal
	Frequency (%)	Frequency (%)
Arrived Alone	5(0.4)	11(0.3)
Families Friends or Relatives	31(2.5)	58(1.7)
Not Hospitalised	862(69.3)	2608(75.4)
People Near the Crash	56(4.5)	130(3.8)
Transported by Ambulance	281(22.6)	627(188.1)
Unknown	9(0.7)	26(0.8)

Hospitalisation mode and Hospitalization Delay

Table 4. and Table 5. show the hospitalisation mode and hospitalisation delay specifics of fatal and non-fatal cases for heavy-duty single-vehicle crashes, respectively. The heavy-duty vehicle drivers' hospitalisation delay differed significantly for both fatal and non-fatal crashes (Chi-square =30.520, p< 0.001). Most notably, 73.04% of drivers not hospitalised in heavy-duty single-vehicle crashes. In fatal crashes, 11.1% of drivers reported to the hospital within 30 minutes after the collision. People near-crash used either their vehicle or ambulance service as a hospitalisation mode to transfer the victim from the crash spot to the hospital. The hospitalisation mode also differs significantly to both fatal and non-fatal crashes (Chi-square =18.74, p< 0.01).

Table 6. Crash type in single heavy-duty vehicle crashes severities

	Fatal	Non-Fatal	Total
	Frequency (%)	Frequency (%)	Frequency (%)
Hit Animal	0(0.0)	12(0.3)	12(0.3)
Hit Object	51(4.1)	224(6.5)	275(5.8)
Hit Parked Vehicle	6(0.5)	16(0.5)	22(0.5)
Hit Pedestrian	53(4.3)	123(3.6)	176(3.7)
Hit Tree	50(4.0)	162(4.7)	212(4.5)
Others	729(58.6)	2011(58.1)	2740(58.2)
Ran Off-Road	49(3.9)	123(3.6)	172(3.7)
Skidding	306(24.6)	789(22.8)	1095(23.3)

Table 7. Crash cause in single heavy-duty vehicle crashes severities

	Fatal	Non-Fatal	Total
	Frequency (%)	Frequency (%)	Frequency (%)
Alcohol Abuse	2(0.2)	8(0.2)	10(0.2)
Animal Involved in Crash	4(0.3)	11(0.3)	15(0.3)
Changing Lane Without Due Care	15(1.2)	24(0.7)	39(0.8)
Dangerous Overtaking	4(0.3)	34(1.0)	38(0.8)
Driving Against Flow of Traffic	21(1.7)	51(1.5)	72(1.5)
High Speed	962(77.3)	2765(79.9)	3727(79.2)
Inattentive Turn	109(8.8)	242(7.0)	351(7.5)
Non-Respect of Rights of Way Rules	67(5.4)	182(5.3)	249(5.3)
Others	60(4.8)	143(4.1)	203(4.3)

Table 8. Driver error in single heavy-duty vehicle crashes severities

	Fatal Frequency (%)	Non-Fatal Frequency (%)	Total Frequency (%)
Carelessness	118(9.5)	321(9.3)	439(9.3)
Distraction	24(1.9)	64(1.8)	88(1.9)
None	264(21.2)	672(19.4)	936(19.9)
Others	38(3.1)	146(4.2)	184(3.9)
Unknown	358(28.8)	1028(29.7)	1386(29.5)
Violation of rule	442(35.5)	1229(35.5)	1671(35.5)

Crash Causes, Crash Type and Driver error

Table 6. gives the spread of crash type for heavy-duty single-vehicle drivers. Among 1244 fatal cases: 306 crashes were skidding (24.6%), 53 hit pedestrian (4.3%), 729 crashes belong to others category (58.6%), 50 hit tree (4.0%), 6 hit parked vehicles (0.5%), and 51 hit object crashes (4.1%). In the case of non-fatal crashes, 789 crashes were skidding (22.8%), 123 were ran-off road vehicle (3.6%), 2011 were others category (58.1%), 162 were hit-tree crashes (4.7%), 16 were hit-parked vehicle(0.5), and 224 were hit fixed objects on the road (6.5%). A statistically

Table 9. Characteristics of crashes involving fatal and non-fatal heavy-duty single-vehicle crashes.

Variable	Test statistic	Nature of difference
Season	Chi sq.=3.408; p=0.333	Fatal crashes are common during monsoon season (32.7% vs. 34.8%)
Day of the week	Chi sq.=12.523; p<0.001	Fatal crashes were more common during the weekdays than at weekends (69.3% vs. 74.5%)
Region	Chi sq.=5.041; p=0.169	Fatal crashes were more common in the Northern region of Tamilnadu than in other regions of Tamilnadu (29.1% vs 30.6%)
Number of lanes	Chi sq.=468.077; p<0.001	Fatal crashes were more common on two-lane roads than the single-lane road (42.8% vs 16.9%)
Central Divider	Chi sq.=541.466; p<0.001	The absence of a central divider can significantly influence fatal crashes (56.1% vs 20.8%)
Junction type	Chi sq.=293.007; p<0.001	Fatal crashes are common in spots that are not junctions (79.6% vs 65.1%)
Traffic control	Chi sq.=5.966; p=0.427	No difference
Road category	Chi sq.=461.246; p<0.001	Fatal crashes are common on state highways (38.2% vs 66.5%)
Weather conditions	Chi sq.=8.229; p=0.144	Fatal crashes are common in fine weather conditions (97.6% vs 98.3%)
Road Conditions	Chi sq.=5.324; p=0.349	No difference
Light conditions	Chi sq.=10.806; p=0.013	Fatal crashes are common in daylight conditions (61.9% vs 65.1%)
Population setting	Chi sq.=9.337; p=0.002	Fatal crashes are common on rural roads (88.7% vs 85.3%)

significant difference (Chi-square =16.92, p < 0.05) was found between fatal and non-fatal crashes. Skidding and hit pedestrian was more common among heavy-duty single-vehicle drivers that resulted in fatal crashes.

Tables 7. and 8. display contributory factors and the driver error in single-vehicle heavy-duty drivers. High speed that includes exceeding speed limits (driving above the speed limits) and inappropriate speed (driving too fast for the given conditions, within limits) was the primary cause for most heavy-duty single-vehicle crashes. The results show that a high incidence of heavy-duty single-vehicle crashes is due to speeding (77.3% fatal crashes versus 79.9% non-fatal crashes). Besides this, inattentive turn (8.8%), non-respect of rights of way rules (5.4%), driving against the flow of traffic (1.7%), changing lane without due care (1.2%), dangerous overtaking (0.3%), animal involved in the crash (0.3%), alcohol abuse(0.2%) were the causes that led to fatal crashes among single heavy-duty vehicles. A statistically significant difference between fatal and non-fatal crashes (Chi-square =16.92, p< 0.05) was observed in this study. Violation of the rule (35.5%) is the single most significant driver error contributing to fatal crashes among heavy-duty vehicle drivers. Furthermore, 118 crashes were identified due to carelessness (9.5%), 24 due to distraction (1.9%), and in 264 cases (21.2%), there is no significant driver error. There was no significant difference in the driver error between the fatal and non-fatal crashes (Chi-square =5.08, p= 0.415).

Environment and Road Characteristics associated with Injury Severity

Table 9. relates fatal crashes to non-fatal crashes on many variables concerning heavy-duty single-vehicle drivers. Fatal crashes among the heavy-duty vehicles were more during monsoon season, in northern Tamilnadu, on two-lane roads, in the absence of central divider, at junction less spots, on state highways, in fine weather, during daylight and on rural roads.

Logistic regression model analysis results:

Table 10. represents the results of simple logistic regression analysis for single heavy-duty vehicle crashes. The driver's demographic variables, road and environment variables were given as the input to the model that may hypothetically influence the outcome variable (fatal or non-fatal). The results of the study show that demographic variables (driver age, license status and mobile use) were statistically associated (p<0.05) with fatal crashes. Simultaneously, authors found in the road and environmental variables considered in the study: region, number of lanes, junction type, road category, presence of road separators, weather conditions and light conditions to be statistically significant for fatal single heavy-duty vehicle crashes.

Heavy-duty vehicle drivers in the working-age group (25-64 years) had lower odds of fatal injury in a crash

Table 10. Results of the logistic regression model in single- heavy-duty vehicle crashes.

Characteristic	Variable	Estimate	Std. Error	p	OR (Odds Ratio)
Region **Ref:** West	South	0.317	0.142	0.025	1.37
	North	-0.307	0.128	0.016	0.74
Number Of lanes **Ref:** Multiple lines	Single	-1.807	0.149	<0.001	0.16
	Two	-0.308	0.142	0.029	0.73
Central Divider **Ref:** No	Yes	-0.937	0.089	<0.001	0.39
Junction Type **Ref:** Cross junction	T Junction	1.341	0.640	0.036	3.83
Road Category **Ref:** Expressways	National Highway	-1.545	0.152	<0.001	0.21
	Other Roads	-1.111	0.189	<0.001	0.33
	State Highway	-1.881	0133	<0.001	0.56
	Village Roads	-0.911	0.173	<0.001	0.40
Driver Age **Ref**: <=17	18-24	0.584	0.269	0.030	1.79
License Status **Ref**: No	Yes	-0.266	0.101	0.008	0.77
Mobile Use **Ref** : No	Yes	3.045	1.237	0.013	21.02

compared to the very young age group (18-24 years) (OR = 1.27 and 1.79 respectively). Drivers holding a valid license had lower odds of fatal injury in a crash compared to the driver not holding a valid license (OR=0.77). Interestingly, the use of mobile phones while driving resulted in a higher likelihood of involving in fatal crashes (OR=21.02) compared to those heavy-duty vehicle drivers who were not using mobile phones at the time of the crash. Heavy-duty vehicle drivers who commute on the two-lane road increased the fatal injury odds in a crash to drivers who commute on a single-lane road.

Discussions and Conclusion

MoRTH 2018 Report clearly shows that Tamilnadu is one of the leading states in terms of crashes (1st position) and deaths (3rd position) in India (MoRTH, 2018). On examing the comprehensive data set from the RADMS database during 2013-2018, It was observed that 27% of fatal crashes in heavy-duty single-vehicle crashes. Simultaneously, the following factors were identified to be most likely to contribute to fatal crashes in heavy-duty single-vehicle crashes: winter season, weekdays, Northern region of Tamilnadu, two-lane road, absence of central divider, junction less spots, state highways, daylight, fine weather, and rural roads.

In logistic regression, various outcomes emerge from patterns in datasets when different denominators are used to compute the odds ratio. The regression analysis outcome shows that drivers aged between 18 and 24 years are more likely to cause heavy-duty single-vehicle crashes. It may be due to drivers' stubborn nature towards traffic environment or unawareness of traffic rules, or rash driving. This outcome is in line with the earlier finding. (Chen and Chen, 2011; Lei and Li's, 2014). Likewise, this study also observed that heavy-duty single-vehicle crashes are more likely to occur in southern regions than in other regions as per zonal classification by the police. A further detailed investigation has to be carried out in this region to know unique contributing factors causing fatal single heavy-duty vehicle crashes.

Approximately 88% of heavy-duty single-vehicle fatal crashes occurred on rural roads. It may be due to poor infrastructure on rural roads. This finding is in line with past studies showing that rural roads contribute significantly to fatal crashes(Chen and Chen, 2011; Islam et al., 2014). The results of the present study also highlight that heavy-duty single-vehicle fatal crashes are more common on weekdays. Also, two-lane roads and the absence of a central divider are significant factors resulting in heavy-duty single-vehicle fatal crashes. Installation of a central-divider, proper signboards on-road, and marking the pavements can reduce the fatal crashes on a two-lane road and where the central-divider is absent.

Unlicensed drivers account for 25% of fatal heavy-duty single-vehicle crashes. This may be due to the risk-taking behaviour of unlicensed drivers (either young or older). A change in such a behavioural aspect can be brought by providing frequent training to heavy-duty vehicle drivers.

Generally, in India, Police investigation officer request the Autopsy to report under Section 174 in The Code Of Criminal Procedure to identify the cause of the death which include blood alcohol concentration (BAC) tests . However in Tamilnadu, People involved in the accidents are subjected to BAC tests without fail to identify the persons driving under the influence of alcohol. Those who do not cooperate for the BAC test are also booked under Section 205 (Presumption of unfitness to drive) of the Motor Vehicles Act, which presumes the drunkenness of the person involved in accident. The authors also like to highlight that, the data reported in this study is the secondary data from the police reports and hence due to data compliance issues and undereporting, actual figures may vary. Mobile phone usage while driving distracts the driver from their primary duty, i.e., driving. The present study results show that heavy-duty vehicle drivers are more likely to be involved in fatal crashes using mobile phones. Such results were observed in earlier studies by (Charles et al., 2010). Installation of alertness devices through audio and visual communication and warning systems to stop the vehicle while using mobile devices can reduce this crash type. Wearing a seat belt decelerates the driver's motion in a vehicle collision and stops them from interacting with the immediate environment. The heavy-duty vehicle structure can also absorb more impact energy and transfer low 'G' forces to drivers in a vehicle collision. As per the Ministry of Road Transport and Highway 2018 report 16.1% (Light motor vehicle), the death is caused due to non-wearing of seat-belts by the drivers and passengers. Road accidents will not decrease by wearing a seat-belt while driving a motor vehicle but the death and serious injuries which are caused by such accidents could be decreased. However, to create strictness in the law, the Central government has hiked the penalties against the rule-breaker by amending the Motor Vehicle Amendment Act, 2019.

There were about 1244 fatalities in heavy-duty single-vehicle crashes in Tamilnadu state over six years, i.e., from 2013 to 2018. Most drivers sustained injuries to multiple body regions in these fatal crashes, followed by the head, hand, chest, face, hip, leg, neck, shoulder, and back body regions. Among non-fatal crashes, most drivers sustained injuries to multiple body regions, followed by leg, hand, head, face, knee, hip, shoulder, neck, chest, buttock and back body regions. This study results highlighted that 13.9% of drivers who sustained multiple injuries are deceased in heavy-duty single-vehicle crashes. An in-depth investigation among the drivers revealed drivers who were not wearing a seat belt while driving sustained injuries to the head, chest, hand and face.

In heavy-duty single-vehicle fatal crashes, most drivers sustained wounds/cuts, followed by severe coma, permanent disfigurement of head or face, abrasion, contusion, fracture or dislocation of bone or tooth and chest trauma. It differs slightly for non –fatal heavy-duty single-vehicle crashes. For non-fatal crashes, drivers sustained wounds/cuts, abrasion, contusion, fracture or dislocation of bone or tooth, followed by other injury modes. Also, unlicensed drivers using a mobile phone and not wearing a seat belt while driving suffered fatal heavy-duty single-vehicle crashes

This study is a population-based study and is for a particular state in India. It may be adapted to a city, district, state, or nation using similar settings. Furthermore, most of the contributory factors found in this study are in line with past studies for a heavy-duty vehicle (Chen & Chen 2011; Islam et al. 2014).

The study outcome highlights that skidding is the primary cause of injury in heavy-duty single-vehicle crashes, followed by hit pedestrians, hit objects, hit trees and ran off-road crashes. For most fatal crashes, high speed is the primary cause of crashes in a heavy-duty single-vehicle. This is identified to be a critical fault with respect to the driver. High speed refers to the driver driving above posted speed limits or driving too fast for given road conditions. Such observations have been highlighted in earlier studies by the same authors for Chennai city in Tamilnadu, especially in the urban highways (Balasubramanian & Sivasankaran, 2019). Following high speed, inattentive turn and non-respect of rights of way rules were identified to be a serious cause for fatal crashes.

Further, violation of rules, carelessness and distraction are significant driver errors identified for fatal heavy-duty single-vehicle crashes. This shows that drivers are unaware of the traffic rules or knowingly violating the rules. To prevent this, proper awareness, educational campaigns, and strict licensing procedures followed by police officer's enforcement activities can mitigate such crashes.

Limitations

Although this study used comprehensive data to investigate the injury patterns in heavy-duty single-vehicle crashes, it limits the researcher to draw inference from the available specific variables. For example, the low incidence of crashes on urban roads made it difficult to predict their incidence and cause severity. Also, limitations exist for police as it is difficult to enter all the details at the crash scene. Factors such as distraction and carelessness (e.g., drinking water, listening to music, talking to co-passenger.) are not captured in detail because of no such facility to enter the data in crash reports. Also, these variables may vary as they depend on witnesses at the crash scene. It may cause deviation from the actual values. Even such detailed investigations were not part of this study, the results from detailed investigations can provide vital insights into future research crash cause in respect of heavy-duty vehicles.

Conclusion

This study investigated the critical contributing factors causing fatal heavy-duty single-vehicle crashes. Drivers aged between 18 to 24 years, using mobile phones while driving, not wearing seat belts, unlicensed drivers, absence of central divider, rural roads were more likely to cause fatal heavy-duty vehicle crashes. Few recommendations from the results of the present study include:

- Installation of low-cost barricades instead of median separators, proper pavement markings, visible and legible signboards, rumble strips can reduce crashes.
- Conducting regular education campaigns, awareness sessions for the heavy-duty vehicle drivers about the traffic rules their violation effect can improve driver safety.
- Installation of devices to alert the driver via audio and visual communication to stop the vehicle while using a mobile phone. Vigorous enforcement and spot fines for drivers who do not wear a seat belt have to be imposed.
- Vehicle skidding is the primary cause of heavy-duty single-vehicle fatal crashes. So, installing an antilock lock braking system will effectively borrow extra time for the driver to steer the vehicle to avoid the crash. This can also be made mandatory for all heavy-duty commercial vehicles
- Enforcing stringent driving license procedures and improving driver training through cutting-edge technologies like Virtual/Augmented/Mixed Reality can improve driver behaviour while interacting with other road users.

Acknowledgments

The authors wish to thank the Tamilnadu police for providing research access to the RADMS. This research did not receive any specific research grants from the funding agencies in public, commercial, or not-for-profit sectors.

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Road Safety Policy & Practice

Developing a Scaffolded, Structured Approach to Road Safety Education in Schools

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Key Findings

- School syllabus development and design are based on the principle of *scaffolding;*
- Scaffold-based programs of learning use the concepts of *scope and sequencing;*
- As children mature, their responsibility to apply skills and strategies can increase;
- An integrated scaffold in road safety is currently lacking in Australasian schools;
- An integrated road safety scaffold could enhance learning, skills and safety.

Abstract

Scaffolding is a well-established approach to education to maximise student learning outcomes. The premise of this paper is that there is a need for formal, scaffolded road safety education (RSE) which can be delivered in schools in Australasia. This paper supports the education system as being expert in matching human growth and developing scaffolds on which to build learning stages and presents arguments to show that an RSE scaffold can and should be drawn up. Schools can provide a structured in-class and real world learning experiences within that scaffold, which, with suitable communication, can be backed up by the home and the broader community. An integrated RSE scaffold across primary through secondary schooling is currently lacking in Australasia, but could be readily integrated in current school curricula. This paper calls for such developments and welcomes further debate and implementation of next steps to achieve this.

Keywords

Curriculum, Road Safety Education (RSE), Scaffold, School Education

Glossary

- Scaffold – a framework to guide teachers to encourage student learning and independence, using the concepts of scope and sequencing
- Scope – the breadth of learning
- Sequence – the order in which learning takes place

Introduction

School-age children are vulnerable road users. As passengers, pedestrians and cyclists they are exposed to harm due to their developing knowledge, skills and experience, propensity to distraction, short stature (lack of visibility to others) and, commonly, a lack of personal protective equipment (Congiu et al, 2008; also Twisk & Vlakveld, 2019). This includes, for example, underdeveloped ability to judge directions from which traffic is approaching, distance and speed of approaching traffic, and stopping distances. Compared to adults, they can act unpredictably, impulsively and have a limited understanding of road rules. It is generally recommended that children require adult supervision at least until the age of nine before allowing some independent walking and cycling in traffic-calmed streets (e.g., Congiu et al, 2008; RCH Melbourne, 2019). Beyond such early independent exposures, many children also will become drivers or riders of motorised vehicles before leaving school, with some jurisdictions allowing moped riding from age 15½ years and car (learner) driving and motorcycle riding typically around age 16 (e.g., Department of Transport WA, 2020; Senserrick & Williams, 2015).

Skills involving an understanding of traffic movement, the use of the senses and decision-making are key to safely coping with the demands of roads and road-related areas and schools specialise in structured and age-appropriate teaching and training (Meir & Oron-Gilad, 2020; Zeuwts, Deconinck, Vansteenkiste, Cardon, & Lenoir, 2020). This is not only beneficial for developing academic skills such as maths and reading, but also for developing skills for life outside school, for example safe travel. Without a structured approach, children may find themselves learning about road use by trial and error in the real traffic environment that on the one hand is too complex and on the other hand too dangerous for the undirected accumulation of learning and experience, whereas guided learning which is both age and experience related learning offers a deeper appreciation of the dangers that road users of all ages face (Schieber & Vegega, 2002).

Recent moves in Europe have been to establish clear educational goals for schools in the area of road safety (ETSC, 2020) and those moves are relevant to the Australasian situation with both composed of high-income countries with similar community problems and possible educational solutions. The lessons in Europe include the need to establish a scaffold for RSE in schools which would identify the appropriate scope and sequence of road safety learning.

'Scaffolding' in the context of education can be considered narrowly as a technique to transfer knowledge from the teacher to student in a staged manner, such as with gradual examples, modelling and questioning that increasingly stimulate more independent thought by the student, such as during a given lesson (Firestone, 2016). Broader than this, Dickson, Chard and Simmons (1993, p. 12), for example, defined scaffolded instruction as "the systematic sequencing of prompted content, materials, tasks, and teacher and peer support to optimize learning". Attributed to early writings of Vygotsky (1978), scaffolding is a well-established educational approach shown to enhance learning outcomes (Jacobs, 2001; Kleickmann, Tröbst, Jonen, Vehmeyer, & Möller, 2015; Wood, 2001). Broader still, scaffolding can be conceived as applicable across a curriculum and across increasing years of schooling, with this latter conceptualisation a key focus of this paper.

The aims of this paper are to identify the need for formal road safety education (RSE) in schools across Australasia, to identify conditions for RSE to be effective and to argue for a scaffolded RSE curriculum. The following sections argue for an RSE scaffold by considering why the focus is on schools, current limitations in school road safety education curricula and how scaffolding might be applied, including examples and supports needed.

Why focus on schools?

Schools can provide structured in-class and real world learning experiences, which are soundly based on human growth and development principles and school education involves a triumvirate consisting of the school, the student and the broader community including the home (Alonso et al., 2020). This provides potential for RSE in schools and at home to follow human growth and development as students grow from being passengers, pedestrians and potentially also cyclists to drivers (e.g., Twisk, Vlakveld, Commandeur, Shope, & Kok, 2014). Safer road users, as expounded in the safe system approach to road safety (Tingvall & Haworth, 1999), is the overriding objective.

With the education system being expert in developing scaffolds on which to build learning stages, students using roads can be guided towards being independent and problem-solvers. By gradually shedding outside assistance, students grow through the stages of being passengers, pedestrians, and potentially also cyclists and licensed drivers; noting not all children will become cyclists or drivers, or progress in this order, and some might also become moped or motorcycle riders. A scaffold need not presume that all students will pass through all stages. Rather, a road safety education scaffold through the school years would not only aim to develop independent road use but also promote generalised personal responsibility in all road user categories within a developmentally appropriate timeframe.

Further contextual points are noteworthy here. Young people appear to be delaying driver licensure beyond school age, including in Australasia, albeit there are some corresponding reports of potential increased engagement in motorcycling (ITF, 2015; Thigpen & Handy, 2018; Wundersitz et al., 2015, 2018). There is an intentional lack of focus on early motorised riding in the remainder of this manuscript given its high-risk nature, generally discouraged prior to at least meeting learner driver eligibility requirements (e.g., NZTA, 2017). Notwithstanding this, the transferability of learning arguments also apply to motorised riding, and all elements of the RSE scaffold should be routinely monitored and updated with shifting trends, as per other school curricula.

Limitations of the current situation in the school education arena

Previous international evaluations and reviews have led to the conclusion that the potential effectiveness of RSE in schools is currently limited (Assaily, 2017; Twisk et al., 2014). In order to identify the current state of implementation in Australasian schools, a search for RSE syllabuses or other references was undertaken of the Australian Curriculum Assessment and Reporting Authority (ACARA) website (the independent statutory authority in Australia, which acts as a source that gives advice on and the delivery of the national curriculum and assessment for education ministers), as well as the websites of each jurisdiction's education authority. First and foremost, specific documentation establishing an educational scaffold that relates human growth and development to learning about being a passenger, pedestrian, cyclist and driver was found to be lacking, moreover, the scope and sequencing of learning activities within an integrated scaffold.

Most Australasian schools were found to include some form of driver education program in later years (e.g., Road Safety Education, 2020), and have access to various resources via their local road authorities and police or other on-line resources for child passenger, pedestrian and cycling safety (e.g., Kidsafe, 2017; Raising Children Network, 2020), as well as various safe routes to school and cycling safety initiatives (e.g., Bikes in Schools, 2020). Irrespective of the format or quality of these resources and programs, they nonetheless are not presented as being part of a cohesive whole, but rather they stand alone and address particular issues; small parts of a bigger picture that lacks definition. Moreover, the base premise of scaffolding in curriculum design is that an adult teacher provides support to the student in order to facilitate learning and to assist in mastering tasks. As tasks are mastered, the instructor progressively transfers more responsibility over to the students, encouraging them to self-reflect and self-regulate their own behaviours. This integrated perspective was not identified relative to road exposures and behaviours.

For example, the approach taken in NSW, typical of many jurisdictions, is for RSE to be taught within Health, as part of the Personal Development, Health and Physical Education (PDHPE) syllabus (NESA, 2018). Whilst the syllabus identifies some key road safety issues, they are only set in the general context of safety, including mention of road safety and train safety examples within the same sentence (e.g., page 62). This is not a true cross-curriculum approach that would involve all school subject areas. The health and wellbeing of students is a core responsibility of every teacher, also known as duty of care and applies, for example, in the world outside of the school environment when taking students on an excursion.

Whilst there is no current integrated scaffold in RSE, there is much that could help shape it (including those abovementioned). There are ample resources that explain human growth and development and the implications for stakeholders in the formal schooling setting. In early years, for example, Piaget (1970) and Vygotsky (1978) developed theories along different lines, but viewed together gave a broad understanding of how learning in an RSE context can take place: whereas Piaget emphasised the child's exploration of their world and the discovery of knowledge, Vygotsky put greater emphasis on the sociological context of learning and creating opportunities for children to learn (MacLeod, 2018). Since the era of Piaget and Vygotsky our understandings of how children learn have advanced as have teaching methods with the advent of electronics in the classroom such as access to the internet. Also, in recent times the concept of the 'school community' has increasingly come to include the home and its potential to contribute to school-based learning, including in the RSE context (DEEWR, 2008; Elkington & Hunter, 2003; NESA, 2018; NZTA, 2013; Waters et al., 2012). The principles expounded from the time of these early researchers and since have a role to play in the development of appropriate knowledge, skills and attitudes in the areas of being a passenger, pedestrian, cyclist and driver, which all need to be tied into a cohesive whole – the safe road user – with the wider context of the safe system.

The following points are notable in the Australian context, for example. At the Commonwealth level:

- There is no cross-curriculum scaffold in RSE and furthermore no specific reference to the exposure of school students' exposure to road danger as an integrated, cross-curriculum priority (ACARA, 2013a).
- Australian Professional Standards for Teachers (AITSL, 2017) do not specifically mandate road safety practice in the school environment or orientation of teachers in their pre-service training or in-service professional development.
- Student wellbeing is indeed a focus in Australian schools as is safety with a view to students reaching their full potential, as demonstrated via the national resource centre, the Student Wellbeing Hub (DESE, 2020); however, again, with no specific reference to road safety.

At the state secondary school level:

- Road safety is a mandatory concept in the Health Education syllabus as part of the general area of safety (e.g., NESA, 2018, see page 45). This implies that the only teachers that, of necessity, have formal training in the safety strand are the Personal Development Health and Physical Education teachers.
- Road Safety is implied in a range of traditional school subjects, for example Human Society and Its Environment and is already a part of the Science curriculum (e.g., Physics, ACARA, 2013b).
- Road safety is relevant also to the teaching of Mathematics, Engineering, Legal Studies, Geography, Commerce and English to name just a few.

At the state primary school level:

- Road safety is taught by generalist teachers who are not as highly trained in teaching safety as Personal Development Health and Physical Education teachers in secondary schools.

Limitations also result from the in-school structure. In the school situation, the day-to-day timetable is structured almost exclusively around group activities, which means that the contribution of schools to RSE is limited in its ability to provide individualised training and sufficient practice in real traffic.

Implementing RSE as a 'whole-of-school approach'

Whilst there are the limitations as outlined above there are moves towards bringing traditional subject areas together in order to pursue a given theme. Experience in schools is showing that taking a 'whole-of- school approach' is more likely to have a positive impact in embedding and sustaining a positive impact across a range of outcomes (Alonso, Gonzalez-Marin, Esteban, & Useche, 2020; Bond et al., 2004; Cross et al., 2011). A whole school approach includes:

- developing a supportive culture, ethos and environment (in RSE, for what Alonso et al. define as PARK– Positive Attitudes to road safety, Risk perception and Knowledge of safe road rules, behaviours and norms);
- ensuring the scope of the students' learning is tuned to the needs and developmental stage of the students;
- sequencing of the teaching programs in accordance with each subject area's syllabus requirements; and
- proactive engagement with families, outside agencies, and the wider community.

There have been many developments in school education that combine the syllabuses of school subjects and are arranged in such a way as to have students from different year levels work together towards a common aim. One such example is the Science, Technology, Engineering and Maths (STEM) concept, with education authorities publishing their own examples for schools (e.g., NESA, 2020). Elements of each of these subjects already comprise reference to the road environment. Under the curriculum a school could have road safety as a STEM theme; for example, personal transportation and its relationship to the environment. Support for a whole-of community approach to RSE has been documented previously (e.g., Elkington & Hunter, 2003; SDERA, 2009).

STEM activities are arranged on a framework of scope and sequence which means that they are tailored to the students' experience and needs. In 2015, all Australian education ministers agreed to the National STEM School Education Strategy 2016–2026 (Education Council, 2015), which focuses on foundation skills, developing mathematical, scientific and digital literacy, and promoting problem-solving, critical analysis and creative thinking skills. That is, it was recognised that in order for STEM activities to be implemented an appropriate scaffold was needed and this has been established. The scaffold shows which activities can be carried out with the different ages and experience of the students. Within that scaffold the scope (extent) and sequence (order) of the activities are fixed. Schools are encouraged to engage with community resources in order to enrich the students' learning and experience. This model of educational organisation is a strategy that could be applied to RSE.

Nonetheless, tellingly, no such scaffold has been developed that takes the growing child from total dependence on parents/caregivers to complete independence as passengers, pedestrians, cyclists and drivers. As far back as the mid-1980s this lack of organisation was identified. In a report by Maggs and Brown (1986, see pages 71 and onwards), the authors were critical of the lack of structure and support for schools. Only recently, an expert panel under the auspices of the LEARN! Project in Europe supported by the Europe Traffic Safety Council established the role of school education in the area of road safety and how that role can be supported (ETSC, 2020). The lessons of that European paper include the need to establish a scaffold for RSE which would identify the appropriate scope and sequence of road safety learning.

Other successful health and wellbeing examples of scaffolding and the whole-of-school education approach are found in the areas of nutrition (Rowe, Stewart, & Somerset, 2010) with regard to suspension of students (Lister-Sharp, Chapman, Stewart-Brown, Sowden, 1999) and detailing the power of positivity (Fizzicseducation, 2020). All three of these areas have the potential to involve all students as does road safety.

The role of the home

The whole-of-school (the school, its students and the parent body) concept recognises that parents have a powerful role to play and, in the road safety sense, in supervising and stimulating the child's traffic experiences (Muir et al., 2017). The involvement of the family in mentoring their children has been demonstrated in research with young children and teenage drivers (Curry, Peek-Asa, Hamann, & Mirman, 2015; O'Toole & Christie, 2019). Overwhelmingly, parental involvement as mentors and role models also has the effect of refreshing their own knowledge and an appreciation of the challenges faced by their children.

To inform their mentoring, parents need to be made aware of their school's program in order to reinforce what is being learnt at school. There needs to be communication between the school and the home in order that the school's efforts in RSE can be followed up by parents/caregivers. The value of this approach was identified in Western Australia and guides for parents/caregivers have been published (SDERA, 2017, 2020). The guides aimed at parents mentoring their learner driver children provide a good indication of how to support children as they learn to use roads and road-related areas. Personal responsibility and a well-informed attitude form the basis of the driver mentor guide and the resources available outside the school system are clearly set out. The connection between the school's efforts and the home is thereby enhanced and this approach can be applied to all stages of the education system. Such a mentoring approach would be appropriate also for the earlier stages of learning, that is, as passengers, pedestrians and cyclists; gradual and graduated learning.

The scaffold taking shape

Scaffolding in education is not a new concept and has been available since the 1960s and exemplified in guides for teachers (Firestone, 2016). The principles can be applied to RSE provided that an accompanying plan of scope and sequence is developed (see for example, SDERA, 2009). There is ample evidence of how humans grow and develop but the need is to apply it to RSE.

The creation of an RSE scaffold would show the interrelationship of the different classes of road user both in the learning sense and the real world. It would also plot the readiness of the child to progress from using roads totally dependent on parent/caregivers to full independence. Along the way the scope of the learning and the sequencing of experiences will be able to be plotted. Conceptually speaking, this scaffold would be built in much the same way as scaffolds that already exist for current school subjects which are all based on the readiness of students to progress from one stage to the next and which allow for the differing learning rates of the students. A major departure from the "traditional" scaffolds would be the inclusion of the role of the home.

Underpinning the scaffold's scope would be the development of students' knowledge of the road environment and road rules, the perceptual skills required for danger and hazard identification and positive attitudes towards students' increasingly independent road use.

There have been many studies that relate to human growth and development. Amongst the most succinct statements by a researcher are those by Roundy (2020) where she points to the general predictability of the stages through which humans pass, being infancy, childhood, adolescence and adulthood. The scaffold would plot the developing needs of the students as they move through experiences of being passengers, pedestrians, cyclists and drivers. At each stage, the students start out being totally dependent on adults through to being totally independent.

Evaluation of a student's progress would be an essential dynamic in the scope of the proposed scaffold and would be an indicator of what could be next on the sequence of learning for the student. Support documents aimed at teachers and families/mentors would need to accompany the scope and sequence section of the scaffold, which would guide assessors as to whether the student is ready to progress to the next stage of classroom and real world experience. Such scaffolding is offered as a desirable practice in all school courses in some jurisdictions (QCAA, 2018).

A transport-related example of this educational concept of scaffolding that can be used as an exemplar is one developed by Transport for NSW (2019) in order to educate parents/caregivers and children on safely using Sydney trains. That program recognises the role that adults play in the process of children learning about the dangers posed by travel on the public transport network and the growing independence of children until they have sufficient maturity and experience in order to travel independently. Successive resources are provided for pre-school, primary school and secondary school students.

Examples of an RSE scaffold to enrich the current curriculum

At the primary school level, an RSE scaffold would be established, centred around learning how to be a safe passenger, pedestrian and cyclist. In secondary education, deeper understanding of a road user's rights and responsibilities are age appropriate, including road rules and legal implications for preventing harm to oneself and others when sharing the road.

A common current perception is that the school curriculum is overcrowded, that it has too much built into it and that schools are being asked to do too much (Hunter, 2018). If RSE were woven into the delivery of traditional school subjects, beyond a specific current focus in PDHPE, it would give real world examples of concepts that are already being taught, not extra elements to be taught. Some indicative examples in other syllabuses include:

- In English:
    - At primary school – understanding age-appropriate road and roadwork signs, such as pedestrian crossing symbols and direction arrows;
    - At secondary school – levels of language – official as opposed to the vernacular;
- In Maths:
    - At primary school – relating speed to distance and time;
    - At secondary school – interpreting blood alcohol readings;
- In Science:
    - At primary school – how and why we wear seat belts;
    - At secondary school – forces at play in a crash;
- Legal Studies:
    - At primary school – the role of the police;
    - At secondary school – road users' rights and responsibilities.

To follow on from the discussion of STEM above, a more specific example of an integrated scaffold during the early secondary school years specific to the topic of seat belts could be:

- Science: forces at play in a crash and the role of seat belts in distributing forces and preventing secondary impacts;
- Technology: development and mechanisms of seat belts to manage vehicle forces;
- English: civil liberty arguments for and against seat belt wearing policies; and
- Maths: calculation of stopping distances as context to sudden stops and crash scenarios that create forces afforded by seat belts.

Next steps

The first step needed is to establish the RSE scaffold. An expert panel consisting of, for example, road safety authorities and researchers, education authorities, universities, education unions and practising teachers could be set up and be tasked with establishing the scaffold in RSE with supporting documents relating to scope and sequence and implementation of RSE in traditional school subjects. This process could be facilitated via Austroads, for example, and seek cross-jurisdiction agreement and adoption, as was undertaken for the STEM scaffold (as noted above). This has the potential to draw together and show the interrelationship of currently available resources in RSE, as well as update and refine to current advances.

Once this could be agreed and established within the curricula, teacher training would be essential. There is a place for road safety in the training for all teachers during their pre-service stage and the professional development of currently-practising teachers. This would sensitise them to the road safety role they can play in their day-to-day teaching and would allow them to deliver authoritatively road safety messages within the context of the lesson when opportunities arise in day-to-day teaching. This would multiply the educational opportunities for students to be exposed to RSE.

An RSE scaffold has the potential to not only draw together and integrate resources already existing, but also show areas in need of further attention. This would require the further development of key resources for teachers, students and parents/caregivers to round out the whole-of-school package and assist in its implementation. Such efforts would not necessarily need extensive new resources but overarching ways to connect and integrate those already available, yet currently fragmented. As noted above, an indication of what can be done in the area of programming that relates to children's growth and development is exemplified by the aforementioned Sydney Rail's teaching package (Transport for NSW, 2019) and this points to what needs to be done across the road safety curriculum. Other potentially suitable teaching resources are referred to in the Towards Zero document (NSW Government, 2018; pp 16-17, 27) and in European guidelines for resource development that have been published (AVENUE, 2020), as illustrative examples among many other existing resources demonstrating the ready potential for translation into practice.

Conclusions

To be effective, road safety interventions must be part of an integrated system, as opposed to the currently isolated strategies and RSE approaches, exemplified by Health Education being the major vehicle for RSE in the overall school curriculum.

Based on the safe system's approach to road safety and human growth and development, a learning program, a scaffold with inbuilt scope and sequencing covering all classes of road users – passengers, pedestrians, cyclists and drivers – needs to be agreed upon, promoted and implemented across all school levels and multiple subjects in order for RSE to have a truly effective role.

There is potential in sensitising all teachers to road safety as part of pre-service and in-service training and professional development across all stages and subject areas of school education. Part of this overall development can give parents and caregivers access to better resources and take an active part in the process of bringing students into the world of informed, independent road use.

The need and the will to improve road child and youth road safety in Australasia is unquestioned and requires multifaceted solutions. Establishing an RSE scaffold upon an already strong foundation of resources would strengthen the role that education can contribute to continuing efforts to reduce road trauma.

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Contributed articles

Commentary on Road Safety

Death and Injury in Motorcycle Accidents: The Utilisation of Technology to Reduce Risk.

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Key Findings

- A motorcyclist in the UK has around fifty times the risk of a fatal accident, compared to car driver.
- This relative risk has more than doubled over the past four decades.
- The risk could be substantially reduced by a radical re-design of the motorcycle.
- The greater application of extant technologies can reduce risk.
- The vulnerability of lower limbs, identified eighty years ago, remains.

Abstract

In the early 1970s in Great Britain, the fatality rate for motorcyclists was twenty times that for a car driver, this relative risk has widened to around fifty in modern times. Motorcycling has not become more hazardous, rather a modest decline in the fatality rate over four decades has been eclipsed by a considerably greater reduction in the rate for car drivers. Travel by car has become safer, with seatbelts, a rigid safety cell and crumple zones, airbags, head restraints, energy-absorbing steering wheels, and shatter-resistant windscreens, all contributing to risk reduction. A motorcyclist, conversely, on most modern machines, has none of these features, with the crash helmet being the only safety feature generally adopted by motorcyclists over the last half century. The risk inherent in motorcycling could be reduced to a similar level as car travel by a radical re-design of the motorcycle to include a rigid safety cell, clad in energy absorbing deformable material, coupled with a rider restraint system. Less radical technological changes that could reduce the risk of injury, or death, include fitted anti-lock braking systems, ideally with integrated stability control, and an integral impact-activated airbag may arrest the forward motion of a rider in frontal impact conditions. The relatively simple measure of increased rider and/or machine conspicuousness can reduce the risk of certain accidents.

Keywords

Motorcycle, Fatality, Accident, Airbag, Relative risk, Anti-lock braking.

Introduction

This report assesses how existing technology could be utilised to reduce the death and injury in motorcycle accidents, and thus potentially reduce the large relative risk of death of a motorcyclist, compared to that for a car driver.

Motorcycle riders in Great Britain have around fifty times the death rate in road traffic accidents, compared to car drivers, per mile travelled, based on averaging data over recent years (years 2012 to 2016, Table 1).

The absolute risk for a motorcycle rider has shown a modest reduction of around 60% over the four decades since the 1970s, with 40% of the level of risk in the 1970s persisting to modern times (Table 1). The risk of fatality in an accident for a car driver, however, has dropped *sharply* over this same time period, with the risk reduced by 84%; thus a driver has around one-sixth the risk of death on the roads, compared a driver in the 1970s (Table 1).

Table 1. The relative decline in car driver and motorcyclist fatalities over 40 years.
Annual fatality rates per billion miles; average of five years data for Great Britain.

Years	Car drivers[a,b,c]	Motorcyclists[c,d]
1972–1976	14.0	290
2012–2016	2.26	121

[a]DofT, (1977), Table 4.
[b]DfT, (2017), Table TSGB0701.
[c]DfT, (2017), RAS30013.
[d]Woodward, (1983), Table 2.

The difference in reduction of the absolute risks has led to an increase in the relative risk. Whereas there was around a twenty-fold relative risk of fatality for a motorcyclist, compared to a car driver in the 1970s, this risk has widened to more than a fifty-fold difference in modern times.

Motorcyclists and car drivers, though, have both benefitted, in terms of risk reduction, from general improvements in road safety and emergency treatment over the decades (DfT, 2015a); car drivers, and occupants, have additionally benefitted from improvements in car safety technology, including:

1. Seat belts
2. The use of a rigid passenger cell combined with deformable outer structures – ubiquitous in modern car design
3. Head restraints, shatter-resistant windscreens, deformable internal structures, and airbags.

(CDC, 1999; Sawyer, 2013).

Additionally, a range of Advanced Driver Assistance Systems (ADAS) are being introduced into more recent car designs – technologies such as electronic stability control, intelligent speed adaptation, blind spot detection, and lane keeping warning devices (EC, 2018).

Conversely, there have been no major changes to motorcycle design since the 1970s, a typical modern machine has no restraint system, nor impact-absorbing structures. The only general change, in terms of safety, has been the introduction of mandatory helmet use (1973 in Great Britain; Maartens et al, 2002).

Factors which contribute to the relatively high fatality risk for motorcyclists are discussed, followed by an appraisal of how extant technologies could be utilised to reduce risk.

Aspects of the, now obsolete, BMW C1 motorcycle are reviewed, as this provides an example of a production motorcycle, which addressed, in its design, many of the inherent vulnerabilities of powered two-wheel travel.

Motorcycling: Risk Factors

A range of factors contribute to the relatively high risk of fatal accident and injury involving motorcyclists, including, the visibility of the machine and rider (DfT, 2015b), the ways risk is perceived by riders (Musselwhite, et al., 2010), engine power (Mattsson and Summala, 2010), the role of speed (WHO, 2015), limitations of the modern helmet (Fernandes & Alves de Sousa, 2013), and lower limb vulnerabilities (NHTSA, 2008b).

Relative Lack of Conspicuousness

Motorcyclists are harder to see than larger vehicles such as cars, and motorists can fail to notice them when looking around the road, commonly referred to 'looked but failed to see' (LBFTS) in road safety literature (DfT, 2015b; Pammer et al., 2018). Motorcycle crashes, on account of another vehicle's driver LBFTS, can occur "…because motorcycles do not feature strongly in a typical driver's attentional set for driving." (Pammer et al., 2018, p. 5). In 2013 in Great Britain, an analysis showed that 47 per cent of other motor vehicles involved in accidents had failed to look properly, as well as 16 per cent of motorcyclists (DfT, 2015b).

The Perception of Risk

Although motorcycling is a statistical outlier in terms of risk of fatality, motorcyclists have reported as viewing, in general, their riding as safe; whereas other road users reported perceiving motorcyclists as being at great risk of an accident, in the results of a study of perceptions of road safety amongst a sample of adult road users in the UK (Musselwhite et al., 2010). As with some car drivers, motorcyclists have admitted to taking risks, though regarding these "…as justifiable and calculated, based on experience and conditions of the road" (Musselwhite et al., 2010, p.11). Road user behaviour is viewed to be largely "under the control of the individual" and regarded therefore as "lower risk" (Musselwhite et al., 2010, p. 8). Having control of a vehicle may lead to the *perception* of lower risk, however, fatalities amongst passengers in road accidents on public transport (buses and coaches),

Table 2. Deaths in road traffic accidents: public and personal transport.
Annual total fatalities in Great Britain; average of five years data[a]

Mode of transport	Fatalities
Bus or coach (occupants)	8
Pedal cycle	108
Motorcycle users	336
Car occupants	791

[a]DfT, (2017), RAS30001; data for years 2012–2016.

where the individual has *no control* over the vehicle, are exceptionally rare in Great Britain. There were an average of eight buses or coach occupant fatalities per year during years 2012–2016; average annual fatality data for public transport (buses and coaches), are compared with that for personal transport users (car, motorcycle and pedal cycle), in Table 2.

There were *zero* passenger fatalities due to train accidents in Great Britain in the nine (financial) years up to, and including, 2015/16 (ORR, 2017).

Engine Power

For a given engine capacity, the power of an engine can vary, and engine cubic capacity has been described as a "poor measure of power" (Langley et al., 2000, p. 659). The fatality risk in accidents was found to increase both with the power, and the power-to-weight ratio, of a motorcycle (adjusting for the estimated annual mileage of riders of different powered motorcycles), in a Finnish study, which included data from 117 fatal accidents (Mattsson & Summala, 2010). The pre-accident speed of the most powerful bikes was found to be 20 km/h, or more, over the speed limit in a large proportion of the fatal accidents (Mattsson & Summala, 2010).

Insurance data for the US has indicated that for the category of machine with the highest power-to-weight ratio ('Supersport' motorcycles), death rates per 10,000 registered motorcycles were nearly four times higher than rates for motorcyclists on all other categories of bike (IIHS, 2007).

The authors of the Finnish study had, however, noted that it is not clear whether the increase of fatalities (with both power, and the power-to-weight ratio), found in their study, was related to characteristics of the bikes, or the riding habits of motorcyclists who "choose the most powerful bikes available" (Mattsson and Summala, 2010, p. 87).

Rider Speed

For all road users, as average traffic speed increases, the risk of an accident increases, and in the event of an impact "the risk of death and serious injury is greater at higher speeds, especially for pedestrians, cyclists and motorcyclists." (WHO, p.21). Although there is a particular increased risk for motorcyclists at higher speeds, 33 per cent of the 5286 motorcyclists involved in fatal crashes in the USA in 2016 were considered to have been speeding (racing, driving too fast for conditions, or exceeding the posted speed limit), compared to 19 per cent for passenger car drivers (NHTSA, 2018). An analysis, utilising multivariate risk models, of data from the German In-Depth Accident Study (GIDAS) database for the period 1999–2017, demonstrated a "…strong and significant relationship between relative speed and injury severity in motorcycle crashes…" for helmeted riders (Ding et al., 2019).

Effectiveness, and Limitations, of Modern Helmets

The use of a helmet reduces the risk of death, or head injury, in the event of an accident; data collected in the USA indicates that helmets are about 37 per cent effective in preventing motorcycle deaths (Deutermann, 2004), and 67 per cent effective in preventing brain injuries (NHTSA, 2008a). There were broadly similar findings reported in the results of a Cochrane Collaboration systematic review, based on data from more than one country, helmets reduce the risk of death in crashes by 42 per cent, and head injury by 60 per cent (Lui et al., 2008).

In the USA, helmet law varies from state to state, with survey results indicating that the overall rate of regulatory-approved motorcycle helmet use was 65 per cent in 2016; of the 5286 motorcyclists killed in road traffic accidents in that year, 41 per cent were not helmeted, based on known helmet use (NHTSA, 2018).

Helmet wear was made mandatory for motorcyclists in Great Britain in 1973, however, contrary to what might have been expected, enactment of the Law did not lead to a reduction in total annual motorcycle fatalities in the immediate following years (Evans, 2020, p. 71, Table 3). Total motorcycle mileage increased during this period, and there had been a high level of helmet usage prior to been made mandatory, factors which could account for the increase in fatalities in the late 1970s (Evans, 2020).

Worldwide, although 169 countries (ninety four per cent) have a national law requiring the use of helmets among motorcyclists (WHO, 2015), in many countries there are legal "loopholes" that may limit the effectiveness of legislation, and so "…only 44 countries have laws that apply to all drivers and passengers, all roads and engine types, require the helmet to be fastened, and make reference to a particular helmet standard" (WHO, 2015, p. 26). The 44 countries are "disproportionately high-income countries in the European Region" (WHO, 2015, pp. 26–27); however, "approximately 80% of motorcyclists killed on European roads sustained head impacts and in half of these cases, the head injury was the most serious." (EC, 2020).

Head Injury amongst Helmeted Riders

Head injury, and death from head injury, may still occur in riders wearing helmets that meet a regulatory standard, due to (i) the nature of the impact exceeding the design limits of the helmet, and/or (ii) insecure fitting of the helmet:

(i) Impacts exceeding Design Limits of Helmets

The widely used ECE 22.05 helmet design standard testing includes a drop test with an impact speed of 5.5 – 7.5 m/s (Ghajari et al., 2008). Other standards, such as

BS 6658:1985 (UK), FMVSS 218 (USA), Snell M2005, and AS/NZS 1698, have some variation in the testing specifications, though they all include a drop test onto a flat anvil (Ghajari et al., 2008). Motorcycle helmet manufacturers design the helmets based on the velocity specified in helmet impact energy absorbing tests, in order to meet the required standard (Fernandes & Alves de Sousa, 2013).

Impacts, in reality, occur at a range of velocities, and, as the (kinetic) energy to be absorbed increases with the square of the impact speed (Fuss et al., 2014), the energy at 10.5 m/s will be approximately double that at 7.5 m/s (the maximum ECE anvil test velocity), and at 15 m/s, approximately quadruple. The deformation of a helmet can therefore reach the design limit at higher impact speeds, and an impact may potentially be "…too severe for any wearable helmet" to protect against (Fernandes & Alves de Sousa, 2013, p. 4).

Current motorcycle helmets can thus be considered effective for 'moderate' speed impacts, however at increasing speeds of impact (and therefore impact energy), a limit will be reached where the capacity for deformation (energy absorption) of the helmet material is attained (Fernandes & Alves de Sousa, 2013); the excess of energy (i.e. that not absorbed by the helmet) will be sustained by the rider.

(ii) Insecure Fitting of the Helmet

The Royal Society for the Prevention of Accidents (RoSPA) cited results, in a 2006 motorcycling safety policy paper, from an analysis of reports of fatal accidents; it had been found that the helmet came off in 20 per cent of fatal crashes; 12 per cent before the crash, and 45 per cent during the crash (Lynam et al., 2001, in RoSPA, 2006). It had been noted in the Hurt Report (USA) that if the helmet fits loosely, the crash impact may cause the helmet to rotate and slip off the head, even though the retention system is fastened, and 5.9 per cent of the helmeted riders involved in the accidents analysed, did not have the retention system fastened (Hurt et al., 1981).

Lower Limb Injuries in Motorcycle Accidents

In his first report (BMJ, 1941) of his studies on death and injury amongst motorcyclists involved in accidents, the Australian-born Oxford neurosurgeon Hugh Cairns (1896–1952) reported a greater tendency to lower limb fractures (particularly compound fractures) in motorcycle accidents, compared to other types of accident. With a view to the future, Cairns suggested that if helmets were more widely worn (thus, as he posited, saving lives), the number of "severe" lower limb fractures "requiring prolonged treatment" may increase, and that their prevention "deserves further study" (Cairns, 1941, p. 470). Walpole S. Lewin succeeded Cairns as Consultant Neurosurgeon to the Army (RCS, 2019), and in a 1956 review "Motor-cyclists, crash helmets and head injuries" written with [Royal Army Medical Corps] Captain W.F.C Kennedy, suggested that the "invalidism from major leg fractures" may "be lessened by the fitting of leg-protection bars to all machines" (Lewin and Kennedy, 1956).

Since these reports (Cairns, 1941; Lewin and Kennedy, 1956), however, there has been no radical change in the design of most motorcycles in terms of leg protection, and the Royal Society for the Prevention of Accidents have reported that around 80% of motorcyclist casualties suffer leg injuries (RoSPA, 2006). Analysis of US National Trauma Data Bank-National Sample Program (NTDB-NSP) data, from 2003 to 2005, indicated that lower-extremity injuries were the most common injuries sustained by motorcyclists, with fractures of the tibia, fibula, and femur the most prevalent of these injuries (NHTSA, 2008b).

Leg protection, where it exists on a machine, might consist of fairing ('cowling') or crash bars (Haworth & Schulze, 1996). Although protective clothing can reduce the risk of less serious injuries to the lower limbs (Haworth & Schulze, 1996), crash bars are not considered effective - the reduction of injury to the ankle and foot has been found to be balanced by an increase of injury to the leg (Hurt Report, 1981). In an impact situation, as the rider on most machines is not restrained, a rider's leg may not remain in the leg space afforded by the crash bar, or fairing (Haworth & Schulze, 1996).

Reducing the Risk of Death and Injury in Motorcycle Accidents

A radically re-designed motorcycle, such as the now obsolete BMW C1, could potentially provide a level of crash protection approaching that of a small car (BMW Motorrad, 2000).

Assuming, however, motorcycle design continues along existing lines, combined Anti-Lock Braking (ABS) and stability systems, and possibly airbags, have the potential to reduce risk (NTSB, 2018, EC, 2020).

The relatively simple change of increased conspicuousness can reduce the involvement in accidents (Wells et al., 2004), and restricting novice riders to less powerful machines may reduce fatalities (Evans, 2020).

Redesigning the Motorcycle

The great increase in car use has been accompanied by considerable improvements in car safety technology. In the 1960s, cars started to be built with safety features such as head restraints, energy-absorbing steering wheels, shatter-resistant windshields, and safety belts (CDC, 1999). The rigid passenger cell/crumple zone combination, now a standard design feature of cars, was first patented by Mercedes engineer Béla Barényi in 1951; in an accident the vehicle's front and rear structures are designed to deform and progressively absorb the impact energy, reducing the risk that the occupant space (safety cell) is impinged (Sawyer, 2013).

BMW Motorcycles introduced, to commercial sale in 2000, a motorcycle (the BMW C1) that addressed most, if not all, vulnerabilities of those riding powered two-wheel machines. The machine has a roll cage, an energy absorbing crumple zone, seatbelts, and a seat that would prevent the rider from sliding under the lap belt in the event of an accident ('anti-submarining' technology) (BMW Motorrad, 2000). Notably, it was designed to provide sufficient head protection to obviate the need for use of a helmet; furthermore, head *movement* in the event of an impact would be limited by a head restraint structure. The roof and windshield, forming part of the safety cell, provided a certain degree of protection from wind and weather (BMW Motorrad, 2000).

The manufacturer claimed the C1 offered comparable accident protection to a European compact car in head-on collisions (BMW Motorrad, 2000). Frontal (head-on) impact occurred in 78% of the motorcycles involved in two-vehicle crashes in the USA in 2007; with half of all motorcyclist fatalities occurring as a result of two-vehicle crashes (NHTSA, 2008c). Many countries granted BMW's request that C1 riders be exempt from national helmet requirements, however, authorities in the UK (an important market for the company), declined to exempt C1 riders (DeAmicis, 2015).

The overall safety worthiness of the design was acknowledged in a contemporaneous review, though a concern was raised over maintaining balance at very low speed due to the rider restraint and higher centre of gravity (Ash, 2001).The reviewer was critical of the decision to not allow exemption of the rider from the requirement to wear a helmet in the UK: "The C1 was designed to be ridden without a crash helmet, and all the safety data - which shows it is much safer than a conventional scooter - was accrued without helmets." (Ash, 2001).

The machine was relatively expensive, and not a commercial success, and was discontinued after a few years (DeAmicis, 2015).

Anti-lock Braking & Stability Control Systems

Motorcycles are, by their nature, less stable than cars, and it is left to the skill of the rider to remain upright, for example, in situations involving hard braking on corners; excessive braking, with consequent loss of control, has been identified as a significant factor in accidents (Teoh, 2011). The locking-up of a wheel, due to excessive braking, can be avoided on machines fitted with an Anti-lock Braking System (ABS), which is available on some machines since being first utilised on a motorcycle by BMW in 1988 (Teoh, 2011). An analysis of data on fatal accidents involving motorcyclists riding ABS-equipped machines, compared with the same models without ABS, revealed a 37% reduction in fatalities amongst the riders of ABS-equipped bikes (period of analysis 2003–2008; Teoh, 2011).

Antilock braking systems provide maximum stopping capability when a motorcycle is in an upright position, when a rider is leaning into a curve, part of the traction needed for braking is already being used for cornering (NTSB, 2018). Stability control systems that link ABS to the lean angle of the motorcycle, provide the benefit of ABS during braking in an upright position, or while cornering, and thus could reduce single-vehicle crashes that involve loss of control and running wide on a curve (NTSB, 2018). A few motorcycle manufacturers currently offer some form of advanced stability control system, though only on specific models (NTSB, 2018).

Airbags

Airbags have been fitted to cars for over 60 years, and there is overwhelming evidence that they are effective at saving lives and preventing serious injury in car accidents, particularly if used with a well fitted three-point seat belt (Wallis & Greaves, 2002). Injuries due to the deployment of airbags in cars can occur, though most (up to 96%) are comparatively minor (Wallis & Greaves, 2002).

The provision of air bags on motorcycles is more complex than in cars, as the dynamics of a crash are more difficult to predict; early crash tests with airbags on motorcycles indicated that an airbag system could be beneficial in frontal impacts (EU, 2020). In the early 1990s, tests with different types of motorcycle fitted with an airbag, indicated that full restraint was not possible above a speed of 30 mph, though in reducing the speed of a rider trajectory, could still be beneficial (Happian-Smith & Chinn, 1990).

Since 2006, Honda Motorcycles has offered an airbag option on the Honda Goldwing model (EU, 2020), a particularly large and heavy motorcycle, currently offered with a six-cylinder engine with a displacement of 1833cc and with a kerb weight of 383 Kg (Honda UK, 2020). The airbag is positioned in front of the rider and sensors attached on the front forks detect changes in acceleration caused by frontal impacts (EU, 2020); frontal impacts are common in accidents involving a motorcyclist and another vehicle (NHTSA, 2008c).

Speed Moderation: Engine Power Restrictions

Placing restrictions on novice riders, such as the power of machine that can be ridden, can lead to a reduction in fatalities, particularly amongst younger riders. Enactment of the UK Helmet Law (1973) did not lead to a reduction in total fatalities in the immediate following years, in

1978 there were 1163 motorcyclist fatalities, a figure not exceeded in any subsequent year, and two-thirds (772) were young males (Woodward, 1983, in Evans, 2020). Implementation (1982–1983) of legislation restricting the engine size, and power, of learner machines, coupled with a new two-part test and a time-restricted provisional licence, led to a *sharp reduction* in total fatalities (Evans, 2020, p. 72, Table 4). The extent to which the restriction of power and capacity of machine that could be ridden contributed to the reduction, is difficult to assess, as there were confounding, contemporaneous, licence and training changes; however, evidence from elsewhere indicates a correlation between increasing engine power and risk of fatality (Mattsson & Summala, 2010), for all riders.

Highway speed limits can also have a direct effect on the incidence of rider fatalities; in Japan, the raising of the maximum speed limit for motorcycles traveling on national expressways from 80 km/h to 100km/h in year 2000 led a 30% increase in the incidence of serious injury or death in accidents (Sumida, 2002).

Conspicuousness

There is evidence to support the intuitive view that a motorcycle rider is more likely to be noticed by another road user if the motorcyclist is more conspicuous. A large New Zealand study, conducted 1993-1996, involving 463 cases (motorcyclists involved in crashes that led to hospital treatment with a severity score >5, or death), and 1233 randomly selected controls from the same region and time period (Wells et al., 2004). Factors were found to *reduce* the risk of crashes that would involve injury or death:

- Wearing any reflective or fluorescent clothing: Odds Ratio (OR) 0.63, 95% confidence interval (CI) 0.42–0.94
- Use of a white, rather than black, helmet: OR 0.76 (CI: 0.57–0.99)
- Headlight on in daytime: OR 0.73 (CI: 0.53–1.00)

Thus, wearing *any* reflective or fluorescent clothing led to greatest reduction in risk, with the data for having ‘headlamp on’ or white (versus black) helmet indicating a reduction in risk, although of borderline significance in this study.

Elsewhere, it has been reported that in Europe “motorcyclists who use daytime running lights have a crash rate that is about 10% lower than that of motorcyclists who do not.” (EC, 2020).

Conclusions

Motorcycling carries the highest risk of death in an accident, in comparison with any other common form of road transport.

A modern helmet, meeting a regulatory standard, and correctly fitted, reduces substantially the risk of death, and risk of head injury; although the wearing of a helmet is mandatory, a motorcyclist in Britain is around fifty times as likely to be killed in an accident, compared to a car driver over the same distance.

The risk of lower-limb injuries, identified in the 1941 report by Cairns as deserving further study, remains largely unaddressed in current motorcycle design.

Measures, summarised in this review, which could be taken to reduce the toll of death and injury, include

1. the wider fitment to machines of:
   a. Anti-lock Braking Systems (ABS), ideally combined with an electronically-linked stability control system, and
   b. an impact-activated airbag system may arrest the forward motion of the rider in the event of a frontal impact (a relatively common accident scenario).
2. Speed moderation, including restrictions on the power of machines that can be ridden by novice riders (in countries that have not already done so).
3. Increased rider conspicuousness, for example, the use of a dipped headlamp, or daylight lights.

The application of measures (i) to (iii) could reduce the risk to motorcyclists; in order, though, to approach the level of protection afforded by a modern motor car, future designs of motorcycles would have to be redesigned around the impact protection of the rider, and thus have a restraint system, and enclose the rider within a rigid structure, clad in (impact) energy-absorbing deformable structures.

Aspects of the design (roll cage, seatbelts and deformable structures) of the, now obsolete, BMW C1, could provide a starting point for the development of inherently safer machines in the future, and, also potentially address the risk to lower limbs.

Funding: This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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ACRS updates

From the President

It would be nice to have a strong public transport system that carried the essential personal mobility burden, and was itself regulated by safety management systems which rewarded safe operators and removed unsafe operators. It would be nice to have a road network which supported safe movement by pedestrians and cyclists, was designed in such a way that prevented crashes, and protected all users from serious consequences when a crash occurs. It would be nice to monitor safety performance purely through the responsibilities of different regulated entities, as happens in rail, maritime and aviation transport. But we don't have these things.

So what do we do? We must continue to focus on the long game required to transform the safety of the road traffic system. The Australasian College of Road Safety must lead the debate on the safety of the system, how a safe road traffic system will need to look and feel, and how we are going to achieve our common goal of eliminating serious road trauma by 2050. The Organising Committee of our conference in Melbourne in September is looking at how to continue to push systems thinking.

But we can't spend all our efforts on scenarios and strategies for some time in the future. We must also get serious on the short game, and no other game is more urgent right now than speed management, speed limits and speed compliance. My first 72 hours back in New Zealand for the first time since the borders went up in March last year, has given me cause to reflect on this. The walk from the Managed Isolation and Quarantine hotel on the Auckland waterfront to take the bus back to the airport was on a network of 30 km/h streets. Congratulations to the people of Tamaki Makaurau, and to the people of Nelson who are benefiting from a similar change process.

But it is the killing fields of rural New Zealand where some of the most dramatic change is taking place. New Zealand lowered the 60 miles per hour rural speed limit in the early 1970s. This was mainly prompted by the oil crisis, but it also stopped fatalities increasing, and led to a sustained decline in trauma. In the mid 1980s, the argument we hear in some low and middle-income countries now ran that cars are improving and roads are too, and the limit should be increased. It is safe to say that the Parliamentary Select Committee did not know what they were doing when they recommended increasing the open road speed limit from 80 km/h to 100 km/h. From a deteriorating situation, the injection of this lethal dose of energy into a system that couldn't cope led to New Zealand's second great fatality spike. Families and communities and health services have been paying for it ever since.

Regional driving in Aotearoa is really about driving up and down and over river valleys and mountain passes. So far, State Highways 6 and 7 have taken me over the Whangamoa Saddle that separates Nelson and Marlborough, and the Lewis Pass on the Southern Alps, up and down the Buller, the Maruia, and the Waiau rivers, and many more besides. What a refreshing change to drive from Nelson to the Rai Valley under an 80 km/h speed limit except for the 60 km/h limits over the most windy and demanding stretches. And further extensive 80 km/h restrictions as I head south.

Some users obviously still need to get used to the new normal, and egregiously dangerous limits remain. Change is happening, but this is difficult laborious work. Automatic speed enforcement needs to be strengthened but the limits being enforced across Australasia remain almost universally too high.

Until we have a much wider set of road traffic systems that can cope, our speed limits must come down. A centrepiece of the College's submission to Australia's National Road Safety Strategy is to prepare a regulatory impact statement of reduced default urban and rural speed limits. The default rural limit of 100 km/h is unnecessarily killing and maiming the people of regional Australia and New Zealand, and the default urban limit of 50 km/h is unnecessarily maiming and killing many more in the city. It was therefore pleasing to see the draft Australian strategy include a commitment to the rural analysis, and we are continuing to push for the urban analysis, in line with the theme of this year's United Nations Road Safety Week.

As for compliance – if COVID19 has definitively concluded one argument it is that we Antipodeans are a compliant bunch, particularly when life and health is at stake. In the longer run, the College is continuing to push for mandatory intelligent speed assist, like the Europeans are shortly regulating for. Driver assistance to comply with lower speed limits? That will give us a real kickstart towards elimination.

Martin Small
ACRS President

From the CEO

By the time this edition of the Journal has been published, my six-month appointment as interim CEO will have come to an end. It has been an absolute delight working back in the road safety field and I have very much enjoyed working with so many dedicated people.

The COVID 19 pandemic saw a level of commitment, funding and action unseen in recent decades. Decisive steps across the country and commitment from all Australians ensured that harm was limited. Of course, even one death is too many.

While there is still quite a way to go with COVID, there are some important lessons to be learned from this response that can help reduce road trauma. It is clear that Australia has the ability, the wealth and the expertise to meet its Vision Zero target, perhaps before 2050. What is required is a level of commitment, funding and action that brings rapid change. There is no room for complacency or business as usual. For decades incremental improvement has been the accepted standard, but the COVID response demonstrates that we can and must do better. Of course, even one death is too many.

In helping the College maintain its course there have been a few highlights over the last six months:

ACRS contribution to the development of Australia's National Road Safety Strategy 2021-2030

ACRS has continued to engage with the Office of Road Safety and other stakeholders during the development of the draft National Road Safety Strategy 2021-2030 (NRSS). In March 2021 we provided a submission on the draft NRSS that reaffirmed our commitment to the following 6 key elements:

- Ministers' 2050 vision for the elimination of fatalities on the road extended to serious injuries
- 2030 targets to reduce fatal and serious injuries by 50% (both raw numbers and as a population rate), backed by related performance and delivery targets
- Publication in easily consumable form, for the public, of infrastructure safety star ratings for all road users
- Safety investment plans and budgets to achieve targeted improvements in safety star ratings
- National Regulatory Impact Statement for lowering the speed limits for urban roads and for rural roads
- Keep pace with European vehicle safety regulation that encourages evidence-based driver assistive technologies, especially intelligent speed assist and autonomous emergency braking.

The submission was drafted in the interest of creating a NRSS which clearly sets out how road trauma will be reduced over the next decade and beyond. Our hope is that the final NRSS will provide a strong platform that ACRS can promote and use to drive our own activity and achieve our common goals of eliminating serious road trauma.

Australasian Road Safety Conference (ARSC) 2021

Preparations for ARSC2021 to be presented on 28-30 September 2021 continue. For the first time the conference will be presented in a hybrid format that will allow in-person participation in Melbourne, while also allowing delegates to attend online.

We again extend our thanks to the ARSC2021 Organising Committee co-Chaired by Mr Chris Brennan (Manager Road Safety Planning, Victorian Department of Transport) and Dr Jeff Potter (Principal Safety Policy Advisor, National Transport Commission) and all of the members of our Scientific, Sponsorship, Social and International sub committees. We look forward to you joining us at ARSC2021 - 28-30 September.

International Outreach

The inaugural meeting of the International Outreach Chapter (IOC) was held in March 2021 with almost 40 members attending the meeting. The meeting included a presentation by iRAP CEO, Rob McInerney who shared a number of practical resources.

The IOC was developed as part of our outreach efforts to Low- and Middle-Income Countries (LMIC's) with the goal of supporting road safety in Asia through the integration of global best practices to eliminate road trauma. The establishment of the IOC has been made possible through a $400,000 grant from the Federal Road Safety Awareness and Enablers Fund.

In 2020, ACRS received a 4-year commitment from the Australian Government through the Federal Road Safety Awareness and Enablers Fund; this support includes a Gold Sponsorship of ARSC and funding to support multiple LMIC Scholarships.

Ministerial Roundtables

During 2020 ACRS facilitated two Ministerial Roundtable discussions focused on Vulnerable Road Users and Heavy Vehicles. These were Chaired by Hon. Scott Buchholz, Assistant Minister for Road Safety and Freight Transport and included key stakeholders within the industry. The College will host a further roundtable discussion focused on rural and regional road users in May 2021.

Journal of Road Safety

The Journal of Road Safety continues to be a highly valued ACRS resource. The Journal's name change in 2020 allowed it to align with its growing international outreach and influence. The change brings with it the additional enhancement of providing a broader frame of evidence and discussion for our ACRS members. The Journal is now distributed each quarter electronically to all stakeholders, dramatically increasing the exposure of the Journal articles.

Operational Changes

When I stepped in as interim Chief Executive Office in November 2020 it was with an understanding that this was to be a brief appointment while the Executive Committee undertook the recruitment effort to secure a CEO. The comprehensive recruitment process has been completed and ACRS looks forward to welcoming the new CEO.

In the meantime, I continue to work with our operational staff, our Executive Committee, and other volunteers across Australasia to ensure that we remain focused on supporting you as we work Towards Zero.

I would like to thank the ACRS President Martin Small, the Executive Committee, and the ACRS staff and volunteers who have made a significant contribution during my time as interim CEO. Your efforts ensure that ACRS will continue to be an influential and effective voice for road safety.

Best wishes,
Nick Clarke
Chief Executive Officer (Interim) - ACRS

ACRS Chapter reports

Chapter reports were sought from all Chapter Representatives. We greatly appreciate the reports we received from ACT, SA, Qld and NSW.

Australian Capital Territory (ACT) and Region

It is difficult to realise that the first quarter of 2021 has come and gone. From the Chapter's point of view, we have noticed that activity is beginning to increase. A good sign for us, for road safety and the community as a whole.

As reported previously, the Chapter has focussed on two specific projects during 2020 and into 2021: Wildlife Crashes and Older Drivers. Naturally progress has been slower than desired but we have made some progress.

The ACT Government has recently requested that the Chapter assist in the management of a Forum it intends to hold in May 2021 on the review of motorcycle licensing. A working group has been established to work with ACT Road Safety and Transport Regulation on the project.

The status of the other two active projects is briefly set out below.

Wildlife Project

A detailed outline of this project was included in our previous Journal report.

Aims

To save lives and serious injury in crashes involving ACT and regional NSW road users and regional wildlife and endangered species; to improve the effectiveness of coordination of data collection and sharing and interventions; and

To promote Joint initiatives between all key stakeholders, supported by integrated funding support from Government and the private and community sectors.

Current Tasks

The Chapter is in discussions with the University of Sydney to develop a project brief that can be used to bring some cohesion to current data available and identify important gaps and as a basis for obtaining financial support for the research from Governments and private organisations.

It is hoped that our next report can indicate significant progress on this project.

Older Drivers

The Chapter and COTA have been actively considering alternatives for the delivery of road safety advice for older drivers in the ACT.

Since our last report, COTA has undertaken a review of programs provided by other States and the Northern

Territory, as well as examining material available overseas. An initial draft has been prepared by COTA and reviewed by the Chapter. Once these comments are considered, the Chapter will organise a workshop of all major stakeholders to assess the information included, the best way to provide the information to drivers and their families, and other services the ACT Government might be able to provide.

Once the details and format are agreed, a final review will be held with the target groups and later released to the public. The Chapter will be involved in managing these activities.

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

South Australia (SA)

Hydrogen Fuel Vehicles - 12 February 2021

The South Australian Chapter hosted a very well attended webinar on 12 February where Scott Nargar, (Senior Manager of Future Mobility & Government Relations, Hyundai Motor Company Australia) gave an interesting presentation. After outlining the context in terms of the drive towards sustainable transport and the situation with Australia's fuel security, Scott gave a comprehensive outline of the technology, including refueling, fuel cell stacks, power train, hydrogen tanks, regulators and pressures and refueling infrastructure. Interestingly much of the drive train is the same as used in Hyundai EVs. He showed examples of the technology in cars, trucks and buses, with heavy transport a particular focus. Scott briefly discussed some opportunities in Australia.

Vehicle safety aspects included that the hydrogen fuel cell cars coming to Australia are 5 Star ANCAP rated, and vehicle identification uses QR Codes in several places around the vehicle along with number plate tags for first responder safety. The QR Codes enable online access to detailed vehicle component safety information.

The presentation is available on the ACRS YouTube Channel - https://www.youtube.com/watch?v=1MgAKB08SPE

Next Event

The SA Chapter is arranging a lunchtime webinar for 7 May 2021 where the Centre for Automotive Safety Research will be showcasing their latest work.

SA Chapter Chair & Secretary
Jamie MacKenzie and Phil Blake

Queensland (QLD)

The Chapter held a virtual seminar on 1 December on Reducing workplace road trauma. The

seminar was conducted in the form of a panel discussion, facilitated by Jerome Carslake, NRSPP

Program Director at MUARC, and featuring Mark Stephens, Fleet Operations Manager at Uniting Care Queensland, and Tim Roberts, Consultant Fleetstrategy.

Chapter members contributed to the ACRS submission on the draft National Road Safety Strategy, coordinated through head office. As Chapter chair and representative of ACRS, Mark King took part in consultation with Brisbane City Council on its Integrated Transport Safety Plan. Chapter member Oscar Oviedo Trespalacios was nominated as the national ACRS representation on the National Research Committee on Roadside Advertising.

The Chapter's Sunshine Coast Sub-Chapter has been active and will host its first meeting on

Wednesday 14 th April on the Sunshine Coast Road Safety Strategy.

The Queensland Chapter AGM will be held on Tuesday 8 th June 2021 at QUT, Kelvin Grove Campus. Venue and virtual link to be confirmed. A seminar will precede the AGM.

QLD Chapter Chair
Dr Mark King

New South Wales (NSW)

Continuing our 2020/21 direction

The NSW Chapter's focus on collaboration, consultation, and communication is continuing with our attendance at many forums, meetings, and workshops. In addition to our regular discussions with the TfNSW Centre for Road Safety, Committee members at the AGM of the Australian Driver Trainers Association (ADTA). Members also engaged with Compass to discuss a NSW project that includes data from over 700,000 connected vehicles.

Seminar series

Since the commencement of the COVID-19 restrictions the NSW Chapter has been limited to delivering online webinars in lieu of face-to-face seminars. Rather than a restriction, the move to online delivery has increase both seminar attendance and reach. Interstate and international attendees are now common. However, the number of organisations delivering online sessions has significantly increased and scheduling seminars so they don't clash, duplicate or overwhelm is becoming an issue.

Safer Vehicles: Opportunities to reduce road trauma by improving the fleet
Thursday 11 March 2021, 12:30pm to 1:30pm
David Beck – Transport for NSW, Centre for Road Safety
Mark Terrell and James Hurnall – ANCAP (Australasian New Car Assessment Program)
Safety

Driver inattention and distraction – November 2020
Nicole Downing, (Qld Department of Transport and Main Roads)
Prof. Michael Regan, (Research Centre for Integrated Transport Innovation, University of NSW)

Details of this and previous seminars are available on the Chapter webpage:
https://acrs.org.au/chapters/nsw/

NSW Chapter Chair & Vice Chair
Mr. Duncan McRae & Dr. Prasannah Prabhakharan

ACRS News

ACRS Submission on Draft National Road Safety Strategy 2021-2030

The Australasian College of Road Safety ('ACRS') have provided feedback to the Office of Road Safety on the Draft National Road Safety Strategy 2021-30 (Consultation Draft – February 2021 https://www.officeofroadsafety.gov.au/sites/default/files/documents/draft-national-road-safety-strategy.pdf) ('NRSS').

ACRS recognises the difficulties that arise when developing such a document and in particular securing common positions notwithstanding the vast array of interested parties. While concerns have been expressed among the ACRS membership that the NRSS has some significant weaknesses, it is important that the process of review and development continues.

The submission (https://mcusercontent.com/a4664bfed5e72009f29785051/files/b04a4cd7-ba5f-49ad-ab61-e1d3c7d37639/ACRS_Submission_draft_NRSS_2021_2030_FINAL.pdf) reaffirms our commitment to the 6 key elements previously identified in May 2020 in our letter to the Deputy Prime Minister:

- Ministers' 2050 vision for the elimination of fatalities on the road extended to serious injuries
- 2030 targets to reduce fatal and serious injuries by 50% (both raw numbers and as a population rate), backed by related performance and delivery targets
- Publication in easily consumable form, for the public, of infrastructure safety star ratings for all road users
- Safety investment plans and budgets to achieve targeted improvements in safety star ratings
- National Regulatory Impact Statement for lowering the speed limits for urban roads and for rural roads
- Keep pace with European vehicle safety regulation that encourages evidence-based driver assistive technologies, especially intelligent speed assist and autonomous emergency braking.

The submission was drafted in the interest of creating a NRSS which clearly sets out how road trauma will be reduced over the next decade and beyond. We hope that the final NRSS will provide a strong platform that we can promote and use to drive our own activity and achieve our common goals of eliminating serious road trauma.

Diary

These events may change due to COVID-19 situation. Please check directly with the event website for latest updates.

UN Global Road Safety Week
17-23 May 2021
https://www.unroadsafetyweek.org/en/home

ICRS 2021: International Conference on Road Safety
9-10 August, Lagos, Nigeria
https://waset.org/road-safety-conference-in-august-2021-in-lagos

Australasian Road Safety Conference 2021
28-30 Sep, Melbourne, Australia
https://australasianroadsafetyconference.com.au/

ICRS 2021: International Conference on Road Safety
25-26 October, Barcelona, Spain
https://waset.org/road-safety-conference-in-october-2021-in-barcelona

Melbourne Convention & Exhibition Centre and Online

28 – 30 September 2021

Towards Zero - A Fresh Approach

The Australasian College of Road Safety (ACRS) and Austroads invite you to attend the largest road safety-dedicated conference in the Southern Hemisphere, the 2021 Australasian Road Safety Conference (ARSC2021).

For the first time the Australasian Road Safety Conference will be offered online and in person in Melbourne at the Melbourne Convention & Exhibition Centre from Tuesday 28 September to Thursday 30 September 2021.

ARSC2021 will showcase the region's outstanding researchers, practitioners, policy-makers and industry spanning the range of road safety issues identified in the United Nations Decade of Action for Road Safety: Road Safety Management, Infrastructure, Safe Vehicles, User Behaviour, and Post-Crash Care.

ARSC2021 will focus on engaging all levels of government and community, from the city to the bush, to move "Towards Zero - A Fresh Approach". The comprehensive 3-day scientific program will showcase the latest research; education and policing programs; policies and management strategies; and technological developments in the field, together with national and international keynote speakers, oral and poster presentations, workshops and interactive symposia.

WHO SHOULD ATTEND?

ARSC2021 is expected to attract 500-700 delegates including researchers, policing and enforcement agencies, practitioners, policymakers, industry representatives, educators, and students working in the fields of:

- behavioural science
- education and training
- emergency services
- engineering and technology
- health and rehabilitation
- policing, justice & law enforcement
- local, state & federal government
- traffic management, and
- vehicle safety

Registration Opening Soon

For further information about the conference please visit **www.australasianroadsafetyconference.com.au.**

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