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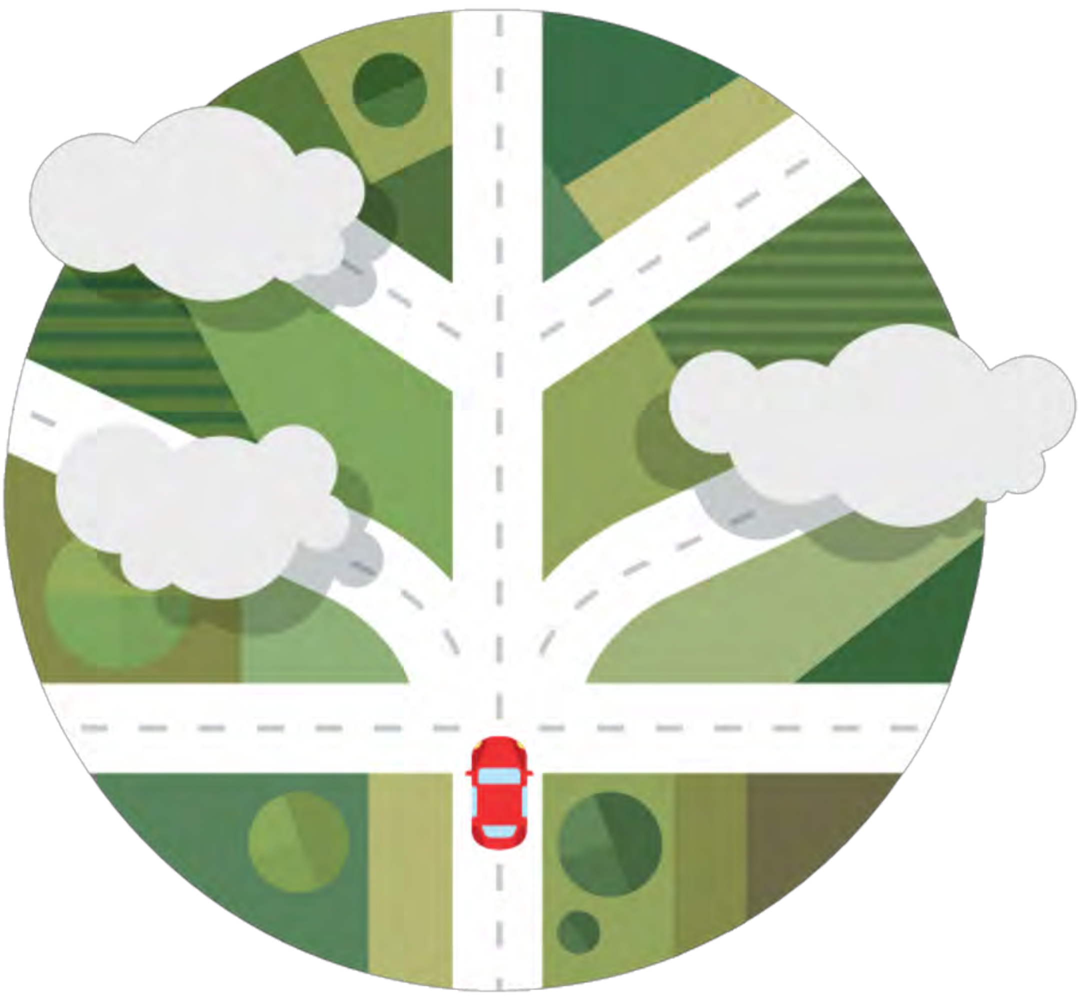
Access Economics



Qualitative and Quantitative Analysis of the New Zealand Road Toll: Final Report

Ministry of Transport

14 March 2017

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Glossary

ACC	Accident Compensation Corporation
CAS	Crash Analysis System
DAE	Deloitte Access Economics
IRTAD	International Traffic Safety Data and Analysis Group
ITF	International Transport Forum
MBIE	Ministry of Business, Innovation and Employment
MoT	Ministry of Transport
NZTA	New Zealand Transport Agency
OECD	Organisation for Economic Co-operation and Development
SRSP	Supplementary Road Safety Package
VKT	Vehicle kilometres travelled

Key findings

Motivated by recent increases in fatalities in New Zealand, this project has sought to better understand the drivers of changes in the level of road trauma in New Zealand over time and at a high level has found that:

- the long-term trend shows **that road travel has become far safer over the last 25 years**, despite a growing population and increasing numbers of vehicles on the road – fatalities have more than halved from 747 in 1985 to 319 in 2015.
- Whilst there have been short-term variations around this trend, **recent increases in fatalities in 2014 and 2015 are more likely to represent a return to the longer-term trend or some unobserved/chance dimension of road trauma**, rather than a systematic increase from the number of fatalities in 2011 and 2013.

This finding is reached through a simulation of what the fatality rate would have been if the conditions driving the dip in fatalities in 2013 were applied to 2014 and 2015.

At the next level of detail, the key explanators of the fluctuations in the New Zealand road trauma over time are found in this modelling (and consistent with the international experience/literature) to be:

- An increase in the **number of vehicle kilometres travelled** (VKT).
  - The analysis suggests a more than one-for-one increase in the number of crashes (and the rate at which those crashes are severe) – this could imply that additional VKT is associated with higher risk travel.
- Increases in the **number of motorcycle registrations.**
  - This aligns with the relative vulnerability of motorcycles, which are less visible to other road users and less stable (Ministry of Transport, 2015).

In interpreting these findings, there is a need to be cognisant of the multi-factor approach that this analysis has taken – that is, **there is no one single factor that can fully explain changes in the level of road trauma**.

There also remains a **reasonable level of unexplained variation in short run-changes in road fatalities**. This could be the result of unobserved factors (such as broader contextual changes relating to changing driver behaviours and attitudes – which may not be currently observed or measured), or could equally reflect the statistical 'chance' dimension to road trauma

When positioned alongside New Zealand's road safety strategy, the findings reinforce that there is a strong need to develop:

- **an ongoing monitoring and evaluation programme** against which progress towards New Zealand's road safety goals can be measured;
- **new/further data** to allow some of the unobservables to be brought into future analysis of this type – for instance a more detailed breakdown of the nature of VKT.

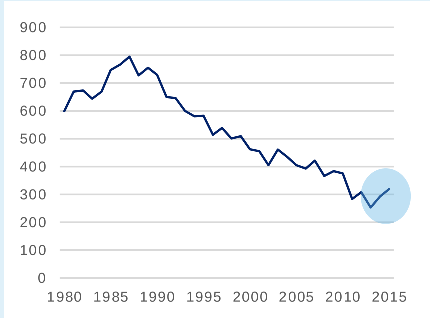
Together, these efforts will allow for a more complete understanding of the drivers of change in road trauma and a more **holistic approach to policy evaluation,** to ultimately create a stronger policy feedback loop and enable the impact of road safety interventions to be continually strengthened.

A safe road system is one increasingly free of death and serious injury

FATALITIES

Road travel has become far safer over the last 25 years, despite a growing population and increasing numbers of vehicles on the road

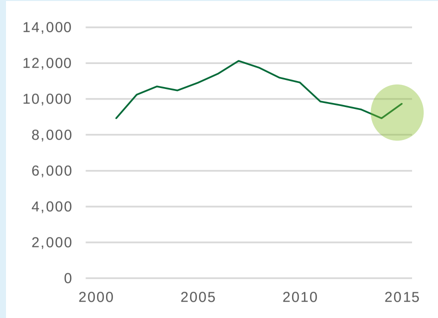
- Whilst there have been increases in recent years, fatalities have more than halved from 747 in 1985 to 319 in 2015.
- Other OECD countries are experiencing similar patterns.



CRASHES

While the number of crashes has fluctuated over time, there has been a downward trend since 2007

- The exception to this downward trend was an increase in 2015, coinciding with the increase in fatalities



The *safe system* approach reflects that the causes of road trauma are multi-faceted

What factors are related to *number of crashes* that occur each week?

Literature and past research suggests:

Findings from this study:

Increases in the number of crashes over time is related to:

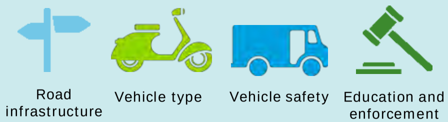
- Increases in vehicle kilometres travelled
- Increases in motorcycle registrations

There is also an unexplained / chance component to the week-on-week variation

- Estimated here to be approximately one-third of the weekly variation in the number of crashes

What factors are related to the *severity* of crashes each week?

Literature and past research suggests:



Findings from this study:

Increased crash severity over time is related to:

- Increases in vehicle kilometres travelled
- Decreases in speed camera detections (in previous weeks)
- Decreases in advertising expenditure (in previous weeks)

Individual risk factors include:

- Being a motorcyclist, pedestrian or cyclist
- Alcohol or drugs involved
- Travelling at inappropriate or high speeds
- Travelling on state highways and other open roads (excluding motorways)
- Male driver involvement

Explaining *recent increases in the road toll?*

Findings from this study:

Recent increases have not been driven by systematic changes in the characteristics of crashes (for example, relating to the individuals or vehicles involved)

Rather, the experience of recent years is more likely to represent:

- a reversion to the longer-term, downward trend; and/or
- unobserved / chance components in the number of fatalities observed

Given the strength of the trend and unobserved variation, more can be understood of what has happened historically, and going forward, how changing contexts and road users are likely to impact historical trends

MONITORING

An ongoing monitoring programme for the Ministry will provide further and timely evidence-based guidance as to which road user cohorts are at greatest risk of crashes and crash severity, and therefore areas where policy interventions are warranted, and are having an impact, by enabling a deeper understanding:

- how interventions impact on factors found to be associated with crash likelihood and severity; and
- the changing relationship between these factors and road safety (e.g. **the strength of the link between risk factors and road trauma**).

DATA

To understand the identified relationships in greater depth, changing contexts and broader trends, there is a need to increase the:

- **frequency of measurement** of key factors, such as vehicle kilometres travelled (to improve the granularity at which data is available – to allow for a richer understanding of VKT), and
- **completeness of data,** such as that relating to drug-driving and distractions in the casualty data, given the increasing focus on these contributing factors as part of ongoing contextual/social changes.

This in turn supports the long-term vision of a *safe system*

Executive summary

Reducing road trauma is an ongoing social imperative for any community. In that respect, while New Zealand has been successful in reducing the level of road trauma (on average) over time, there are annual fluctuations which can be difficult to decipher – for instance fatalities falling to 284 in 2011 and 253 in 2013, and subsequently rising to 319 in 2015[1].

This experience aligns with many other OECD countries – with longer-term declines in fatalities (hypothesised to be largely the result of improved road infrastructure and vehicle safety) being counteracted by increases in more recent years, most notably in Israel (15.4% increase between 2014 and 2015), Finland (13.5%) and Austria (10.5%; OECD/ITF, 2016).

To investigate the drivers behind the observed trends, the Ministry of Transport (the Ministry) has commissioned a rigorous study into the observable short and long-term drivers of road trauma in New Zealand, to ultimately inform an ongoing research and monitoring agenda. This in turn supports the achievement of the *Safer Journeys* strategy, which articulates the long-term vision of having 'a *safe system*[2] increasingly free of death and serious injury.'

Existing New Zealand and international evidence
A review of the New Zealand and international literature was undertaken, in order to understand and identify:

- the factors to be included in the statistical analysis;
- the likely nature of their relationship with road trauma; and
- broader contextual factors that could be changing those relationships over time.

This literature identified a number of factors for inclusion in the statistical analysis. Table i summarises how they are typically understood to influence the components of the *safe system* approach and crash likelihood and severity.

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[1] 328 in 2016 (provisional), Ministry of Transport
[2] A *safe system* aims to reduce road risks and minimise the consequences of road trauma through policies targeting the four components of the road system: roads and roadsides, speed, vehicles and road use, whilst acknowledging that road users are vulnerable to injury and prone to error.

Table i : Summary of components of road safety influenced by factors

Factors	Safe System				Crash risk	Crash severity
	Roads	Speeds	Vehicles	Users		
Road infrastructure	✓	✓			✓	✓
Vehicle safety			✓		✓	✓
Type of vehicle			✓			✓
Public education and enforcement		✓		✓	✓	✓
Economic activity (proxied by VKT)				✓	✓	
Weather, seasonality, time of day				✓	✓	
Overseas licence holders				✓	✓	✓

Other, broader contextual factors that were identified (and their impact on road trauma) include:

- changing media consumption habits – on the effectiveness of road safety advertising;
- increasing prevalence of mobile phones – on driver distractions;
- an ageing population and pedestrian incidents – on crash severity;
- sharing of roads with cyclists;
- impact of second-hand vehicle importation laws – on the composition of the New Zealand vehicle fleet and its crashworthiness; and
- increasing road congestion – on the types of crashes that occur.

Whilst these factors are not explicitly included in the modelling (due to the lack of data currently available), they nonetheless point to wider, societal changes that future road safety policy and interventions should be cognisant of.

Analytical approach

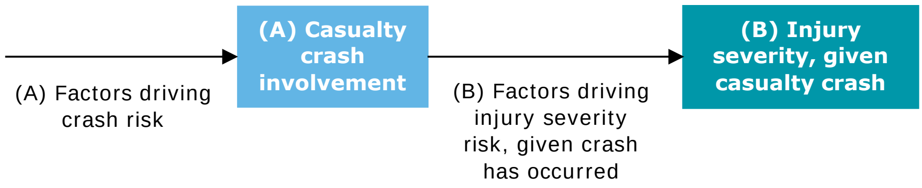
Informed by the literature[3], a structured series of statistical analyses were undertaken to establish the factors most likely to be driving the short- and long-term changes in the level of road trauma in New Zealand over the last 15 to 20 years[4], comprising:

- **Component A**: modelling factors hypothesised to have driven changes in the number of crashes that occurred each week, over time;
- **Component B**:
  - identifying the proportion of crashes that involved a serious or fatal injury each week, over time – to capture the longer-term drivers of the severity rate; and

[3] In particular, the statistical approaches employed by Kockelman and Kweon (2002), Weiss et al (2014), and O'Donnell and Connor (1996). In comparing with previous research undertaken in the New Zealand context – the methods used in this analysis most closely align with those employed by Keall et al. (2012) and Infometrics (2013b). Taking longer term trends as given, both sets of analyses explore the drivers of short term fluctuations in road trauma.

[4] Statistical modelling allows the association of individual factors with the road toll to be systematically isolated and identified. The data used goes back between 15 and 20 years.

  - modelling the key risk factors for severe and fatal injury, at an individual casualty level – to capture the crash- and individual-specific characteristics of interest.



The separate modelling of crash risk (Component A) and crash severity (Component B) allows for the consideration of differences in relationships across these two components.

These results were then further analysed to understand the extent to which observed characteristics of crashes could explain recent increases in road trauma.

Component A: Number of crashes over time

The first component of the modelling found that over the long-term there has been a strong and sustained decrease in the number of crashes since 2000. With particular regard to short-term variations, the analysis found that:

- A 1% increase in VKT associated with a 2.5% increase in the number of crashes.
  - This could be associated with changes in the nature of VKT (such as more rural, rather than urban travel, or different driver behaviour) – but further research is required to understand the risk profile of additional VKT.
- A 1% increase in the number of motorcycle registrations was associated with a 1.6% increase in the number of casualty crashes.
  - This aligns with the relative vulnerability of motorcycles – which are less visible to other road users and less stable (Ministry of Transport, 2015).

It is important to note that these associations (and all associations found in this study) relate to the variation in the number of crashes over the full time period of analysis – not any individual week or year.

Despite the strength of these findings, approximately one third of the variation in the number of crashes each week was unable to be explained by the statistical model, and could relate to other, unobserved or currently unmeasured factors (such as broader contextual changes relating to changing driver behaviours and attitudes).

The results of this analysis also found that an increased number of enforcement notices issued in the previous week of 1% is associated with a decrease in the number of crashes of 0.1% in the current week. While not as material as VKT and motorcycle registration, this result provides affirmation of the importance of this road safety intervention.[5]

[5] It was also found that the proportion of vehicles detected above the posted limit was negatively associated with the number of casualty crashes, with a lag length of 10 chosen based on magnitude and significance. Testing revealed that the estimated effect was significant between lags 7 and 12, with no significant variation in its magnitude.

Component B: Severity of crashes

The second component of the modelling, to understand the factors that have driven changes in the **severity of crashes** since 2000, found that:

- A 1% increase in VKT is associated with an increase in the rate of serious injury crashes (by 2.9%) and fatal crashes (by 1.9%) per casualty crash.
  - This could similarly be the result of changes in the nature of VKT (such as more travel on rural roads) – likewise suggesting the need to further explore these differences.
- A 1% increase in speed camera detections six weeks earlier is associated with a 1.2% decrease in the number of serious crashes (given that a casualty crash has occurred).
  - Similarly pointing to the presence of a deterrent effect.
- Increases in advertising expenditure four weeks earlier by 1% is associated with a reduction in the proportion of crashes that result in severe injury by 0.07%.
  - This could be thought to relate to the time it takes for advertising to translate into awareness and changes in attitudes and behaviours.

Beyond the analysis of the factors explaining short- and long-term road trauma trends in New Zealand, statistical analysis was also undertaken to identify the cross-section of **key risk factors for suffering a severe injury or fatality** (rather than a minor injury) since 1995, given involvement in a crash.

Table ii describes the impact of a selection of the most important risk factors, the most notable being:

- being a motorcyclist, cyclist or pedestrian greatly increases the risk of a severe or fatal injury relative to an individual travelling in a car, reflecting the relative fragility and vulnerability of these road users;
- casualty crashes where alcohol or drugs, or inappropriate speeds were a contributing factor are also more likely to result in severe or fatal injury, reflecting the effects of impairment and high speed crashes, respectively; and
- casualty crashes on rural state highways and other open roads (which are more likely to be single carriageway and have fewer safety barriers installed) are more likely to result in severe or fatal injury, relative to crashes on minor urban roads, capturing the more severe consequences of high speed crashes.

Table ii : Severe and fatal injury likelihood associated with risk factors

Risk factor	Relative to	Severe injury likelihood (relative to minor injury)	Fatal injury likelihood (relative to minor injury)
Motorcyclists	Travelling in car	20.5 percentage points	2.8 percentage points
Pedestrians	Travelling in car	28.9 percentage points	11.2 percentage points
Cyclists	Travelling in car	24.7 percentage points	6.5 percentage points
Travelling in truck, SUV or bus	Travelling in car	-0.4 to -2.3 percentage points	-0.2 to -1.8 percentage points
Alcohol or drugs	Other crash factors	5.9 percentage points	1.9 percentage points
Inappropriate speed	Other crash factors	2.7 percentage points	1.4 percentage points

Risk factor	Relative to	Severe injury likelihood (relative to minor injury)	Fatal injury likelihood (relative to minor injury)
≥ 100m/h speed zone	50km/h to 70km/h speed zone	2.0 percentage points	0.7 percentage points
State highways (urban and rural) and other open roads	Minor urban roads	2.6 to 3.4 percentage points	1.0 to 2.1 percentage points
Male driver involved in crash	No male drivers involved in crash	1.2 percentage points	0.9 percentage points
Restricted or learner licence driver	Full licence driver	-0.1 to 0.5 percentage points	-0.1 percentage points
Two vehicle crashes	Single vehicle crash	-1.3 percentage points	-0.2 percentage points

Note: For some risk factors a range is noted because the estimated effects relates to multiple factors (for instance, trucks are considered separately from SUVs or buses – but are grouped here for the purposes of brevity).

These findings reinforce that there are a variety of severity risk factors relating to the characteristics of a crash, and affirmed what has been previously found in the literature from New Zealand and other jurisdictions – with male drivers, relative inexperience, speeding, alcohol and/or drug presence, and light vehicle types being key risk factors for more severe crash injury outcomes.

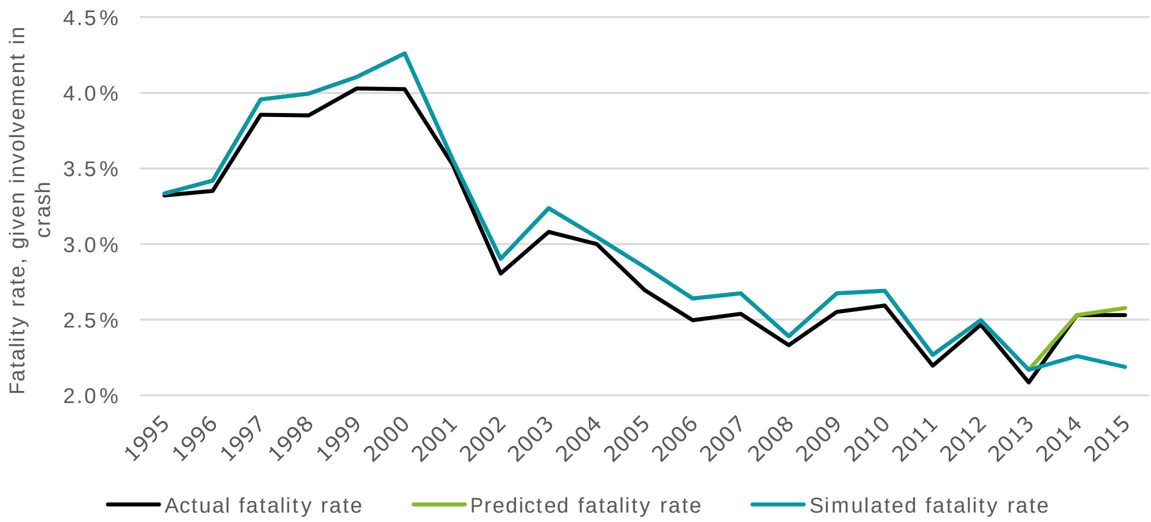
Understanding what this means in the broader context

The final component of the modelling sought to understand what these identified drivers and risk factors meant in the context of recent trends in road fatalities (both the historical lows and subsequent increases). This analysis seeks to answer the question, "What would the fatality rate have been if the external conditions driving the dip in fatalities in 2013 were applied to 2014 and 2015?"

Chart i seeks to understand what the fatality rate would have been if the conditions driving the dip in fatalities in 2013 were applied to 2014 and 2015, by comparing the:

- Actual fatality rate (black line);
- Predicted fatality rate (green line)
  - Which removes the unexplained component of fluctuations from the Actual fatality rate
- Simulated fatality rate (blue line)
  - Which applies the average 2013 fatality risk to 2014 and 2015.

Chart i : Comparison of actual, predicted and simulated fatality rates



Source: Deloitte Access Economics

Essentially, this analysis implies that the historically low number of fatalities in 2013 was more likely a reflection of an abnormal year – driven by broader, unobserved factors and trends, rather than the result of some systematic change in the nature of crashes themselves, and therefore more likely that the increases in fatalities in 2014 and 2015 is likely to represent a reversion to the longer-term trend.

- If the increases in 2014 and 2015 were instead being driven by the characteristics of the crash – the simulated fatality rate would have been closer to the predicted fatality rate. This is because the simulation is based on the known characteristics of fatalities in 2013, not the unknown factors that were present in 2014 and 2015.

Implications for ongoing monitoring and research

An ongoing monitoring programme for the Ministry will provide further and more-timely, evidence-based guidance as to which road user cohorts are at greatest risk of crashes and crash severity, and therefore areas where policy interventions are warranted, and are having an impact. It will also therefore allow for an improved understanding of progress towards the long-term vision of the *Safer Journeys* strategy.

In particular, the initial monitoring framework outlined in Section 4.2 of this study will enable a deeper understanding among policymakers and researchers of:

- how interventions impact on factors found to be associated with crash likelihood and severity; and
- the changing relationship between these factors and road safety (e.g. **the strength of the link between risk factors and road trauma**).

Further, and in particular respect of the available data, the findings of this study reinforce the continued need to enhance the:

- **frequency of measurement** of key factors, such as vehicle kilometres travelled (to improve the granularity at which data is available – to allow for a richer understanding of VKT), and

- **completeness of data,** such as that relating to drug-driving and distractions in the casualty data, given the increasing focus on these contributing factors as part of ongoing contextual/social changes.

A number of other areas for future and ongoing research are also identified, including exploring the impact of contextual changes such as: (1) the effects of driving while impaired by drugs; (2) the compounding effects of drug and alcohol impairment; (3) high-risk locations and crash types for cyclists and pedestrians; (4) changing mobile phone and device use in vehicles; and (5) how increases in road congestion might affect the types of crashes that occur. Improvements to the existing and new data collected will allow for more complete analysis and conclusions relating to these research questions, and would ideally precede (or be a part of) these studies

In the end, there is a need to ensure that future Ministerial (and supporting) effort builds the evidence-base for what road safety interventions work (and equally, what doesn't work) in reducing road trauma. This will better ensure that a balanced view of investment prioritisation is taken, and that interventions with the greatest impact, subject to their costs, are implemented. Reductions in road trauma is of broad interest, given its life-changing impact not just on those individuals involved in crashes, but their families and wider community, and the significant economic and social costs associated.

Deloitte Access Economics

1 Introduction

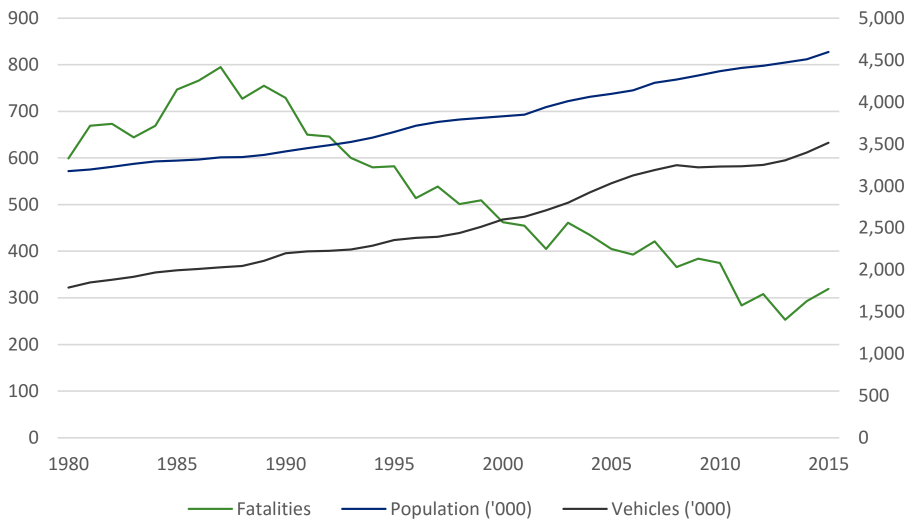
The Ministry of Transport (the Ministry) has commissioned Deloitte Access Economics to undertake a qualitative and quantitative analysis of the New Zealand road toll. The primary purpose of this study is to understand the factors that have contributed to changes in fatalities and serious casualty crashes in New Zealand over time – and the reasons for substantial fluctuations in the road toll over recent years.

This chapter outlines the New Zealand road safety context, motivations for the study and the structure of the remainder of the report.

1.1 Road trauma and road safety in New Zealand

Over the last few decades, strong progress has been made in reducing the road toll in New Zealand, from 747 fatalities in 1985, to 319 in 2015, despite increasing numbers of vehicles and a growing population. At the same time, each year is characterised by short-term fluctuations in the road toll, notably the fall to 284 fatalities in 2011 (from 375 in 2010), and further falling to 253 fatalities in 2013, followed by increases in 2014 and 2015 (Chart 1.1).

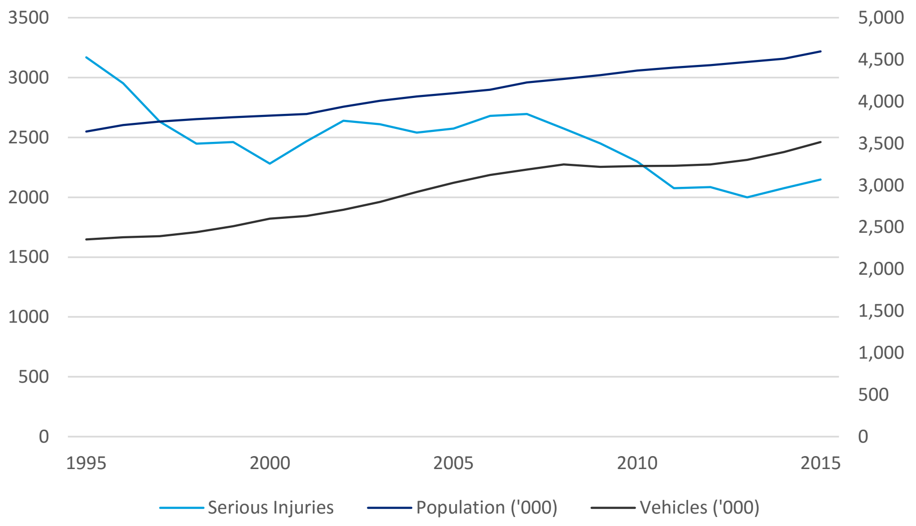
Chart 1.1 New Zealand road fatalities (1980 to 2015)



Source: Ministry of Transport (2017). Note: Fatalities are shown on the left Y-axis; Population and vehicles are shown on the right Y-axis.

The number of serious road injuries each year has likewise reduced, from 3,168 in 1995 to 2,148 in 2015 (Chart 1.2), and again there have been substantial fluctuations over time with the lowest number of injuries in 2013 (1,999).

Chart 1.2 New Zealand serious road injuries (1995 to 2015)



Source: Ministry of Transport (2016). Note: Serious injuries are shown on the left Y-axis; Population and vehicles are shown on the right Y-axis.

The collective view of the New Zealand (and international) road safety community is that there is more progress to be made and lessons from other jurisdictions to be drawn in reducing both fatalities and injuries. Reductions in road trauma is of broad interest, given its life-changing impact not just on those individuals involved in crashes, but their families and wider community, and the significant economic and social costs associated with crashes – in the form of health care, lost wages and reduced quality of life.

New Zealand's overarching approach to road safety is reflected in the *Safer Journeys, New Zealand's Road Safety Strategy 2010-2020*. The strategy articulates the long-term vision of having 'A safe system increasingly free of death and serious injury', and how it will be achieved, through the continued use of the Safe System philosophy.

A Safe System aims to reduce road risks and minimise the consequences of road trauma through policies targeting the four components of the road system: roads and roadsides, speed, vehicles and road use, whilst acknowledging that road users are vulnerable to injury and prone to error. The Ministry's strategy describes a number of actions, drawing in part, on the experience of Australian jurisdictions, including mandating vehicle safety features, setting appropriate speed limits, increasing enforcement activity, improving road infrastructure, and undertaking public education campaigns, to achieve its vision.

The *Safer Journeys Action Plan 2016-2020* (National Road Safety Committee, 2016), details the steps New Zealand will undertake to achieve its vision, and focuses on four key areas where greater progress towards a Safe System is required, namely:

- *enabling smart and safe choices*, by providing greater real-time feedback and information through the use of technology, which will reduce errors and increase compliance with road rules;

- *making motorcycling safer*, given the additional vulnerabilities that these road users face and the minimal reductions in road trauma for motorcycle users over the last 15 years;
- *ensuring roads and roadsides support safer travel*, given the residual risk posed by high risk roads (such as certain urban arterial routes and rural roads); and
- *encouraging safe vehicles*, by taking actions to increase the level of vehicle safety features across the fleet, to prevent or reduce the effects of human error.

1.2 Motivations for this study

This project aims to explore the nature of changes in the road toll in New Zealand and provide a richer understanding of the drivers of those changes. This will be used to:

- inform Ministers and the public of the underlying factors that have driven changes in the road toll in recent years, particularly the decline in fatalities in 2011 and 2013, and increases in subsequent years; and
- improve the Ministry's understanding of the impacts of different factors and road safety interventions on the road toll, thereby allowing the Ministry to develop an ongoing monitoring programme and identify areas to prioritise future road safety research (and ultimately intervention).

1.3 Report structure

This report presents the findings of this analysis and is structured as follows:

- Chapter 2 describes the New Zealand and international literature around the factors that have been shown to influence road trauma, and the magnitude of their impact;
- Chapter 3 sets out the datasets used, modelling approach and modelling results; and
- Chapter 4 presents the key findings from this study, and the implications for the Ministry's ongoing monitoring programme and research agenda.

Detailed appendices that describe the data, modelling approach and results are also included.

2 Literature review

This chapter briefly examines the literature relating to the key factors that are commonly thought to influence the road toll. This allows for a strong theoretical structure to this study's approach to be established, and ensures that empirical techniques that align with the best available data (and accordingly allow for the realisation of their explanatory power) are applied.

2.1 International trends

Globally, trends in road fatalities are similar to those observed in New Zealand. In New Zealand there has been a 37% decrease in fatalities between 2000 and 2014, as compared to a 42% decrease in fatalities in the 32 International Traffic Safety Data and Analysis Group (ITRAD) countries over the same period, and a recent increase in fatalities in 2015 for 19 countries, with Israel (15.4% increase from 2014), Finland (13.5%) and Austria (10.5%) experiencing the fastest increases (OECD/ITF, 2016).

The longer term trend is thought to have been the result of improved road infrastructure and vehicle safety, and the downturn in economic activity in 2008, which would have reduced overall travel volumes, particularly for high risk groups (young male drivers; OECD/ITF, 2015). In light of improving economic conditions in countries most affected by the downturn, increases in the 2015 road toll are to be monitored carefully, to understand whether they are part of a broader trend that requires a policy response (OECD/ITF, 2016).

The types of road users being fatally injured has also changed over time- - with fewer fatalities for car occupants in most countries, but more fatalities for motorcyclists, cyclists, pedestrians and those aged 65 and over (OECD/ITF, 2016). This suggests a need to ensure that road safety policy targets changing cohorts of vulnerable road users, who are more susceptible to severe injury, as well as continuing to reduce the prevalence of risky behaviours (such as drink-driving, speeding and use of restraints and helmets; OECD/ITF, 2016).

2.2 Factors thought to influence road trauma

This section outlines a number of factors identified in the literature as having an impact on road trauma, whether that be through influencing the number of crashes, or the injury severity of crashes given that a crash has occurred. Table 2.1 summaries the impact, found in the literature, which each factor has on the components of the *Safe System* approach, and crash likelihood and severity.

Table 2.1 : Summary of components of road safety influenced by factors

Factors	Safe System: Roads	Safe System: Speeds	Safe System: Vehicles	Safe System: Users	Crash risk	Crash severity
Road infrastructure	✓	✓			✓	✓
Vehicle safety			✓		✓	✓
Type of vehicle			✓			✓
Public education and enforcement		✓		✓	✓	✓
Economic activity (proxied by VKT)				✓	✓	
Weather, seasonality, time of day				✓	✓	
Overseas licence holders				✓	✓	✓

2.2.1 Road infrastructure

Road infrastructure has numerous dimensions – including road condition, camber, lane width and separation, lighting, roadside hazards and safety features, and expenditure on road infrastructure needs to be greater than the amount required to simply maintain the current condition of roads in order to have an additional overall impact (Stroombergen, 2013).

Stroombergen (2013) found in the New Zealand context that 19% of the change in the fatality rate between 1990 and 2012 could be attributed to improvements in road infrastructure (measured as real net investment per unit of travel).

This is supported by econometric findings in the Australian context (BITRE, 2012), which found that the black spot treatments reduced fatal and casualty crashes at treatment sites by 30%. Roundabouts were the most effective treatments, followed by new signals during the day and altering of traffic flow direction.

Road design also has the ability to influence the speed at which road users choose to drive – explicitly, through road signage and markings, and implicitly, through road geometry (narrow roads, or those with rough surfaces are likely to induce drivers to travel more slowly) and roadside environment (number of roadside objects impacting on peripheral vision and perceived speeds). Manipulating road design to enable greater alignment between the actual appropriate speed of the road, and the perceived appropriate speed of the road could have positive impacts for road safety (Edquist et al, 2009).

2.2.2 Vehicle safety technology

Improvements in vehicle safety can lead to improved road safety outcomes in three ways:

- reducing the likelihood of a crash (e.g., through electronic stability control, ESC or auto-emergency braking);
- reducing the injury severity of occupant casualties, given a crash (e.g., through seatbelt reminder systems and side curtain airbags); and
- reducing the likelihood that other road users are impacted in a crash (through improved vehicle design) (Ministry of Transport, 2010).

These improvements are generally analysed through the examination of data relating to vehicle year of manufacture – which is correlated with the general level of vehicle safety features. This is particularly important in the New Zealand context, where the majority of light vehicles entering the fleet in 2015 were used (54%, with an average age of 9.4 years). These used vehicles would, on average, have fewer safety features than a new vehicle entering the fleet in 2015 (Ministry of Transport, 2016).

The cross-sectional crashworthiness of the New Zealand vehicle fleet improved by 18% between 2000 and 2010 (Budd et al, 2015). In addition, the risk of a fatality or serious injury to drivers decreased by 78% between 1983 and 2008 (Newstead et al, 2016). This is supported by findings from Stroombergen (2013) that 44% of the decline in fatalities in New Zealand between 1990 and 2012 could be attributed to improvements in the vehicles, and highlights the importance of vehicle safety features in reducing road trauma.

2.2.3 Type of vehicle

In addition to vehicle age, the type of vehicle can impact upon the severity of road trauma, in crash situations involving heavy vehicles and light passenger vehicles.

Collisions involving articulated trucks, rigid trucks and buses all result in increased risk of death or injury to drivers of light vehicles, particularly for those driving light passenger cars, small passenger cars and compact 4WDs (Delaney et al, 2007). Given that the vehicle fleet is trending towards a more bimodal distribution of masses, crashes involving vehicles with significantly different mass are more likely, and more likely to lead to more severe injury outcomes, particularly for the lighter vehicle (Newstead et al, 2016).

Motorcyclists are also more vulnerable to road trauma than other road users, given motorcycles provide less protection to a rider than a car to its occupants, are less visible to other road users and are less stable. This results in an average risk of injury or death being 21 times higher for motorcyclists than car drivers, when controlling for the distances travelled by motorcycles and passenger cars, respectively (Ministry of Transport, 2015).

2.2.4 Public education and enforcement

New Zealand has used advertising to target road safety since the introduction of the Supplementary Road Safety Package (SRSP) in 1995. Since then, road safety themes targeted by the NZTA and Police include:

- drink and drug driving;
- speeding;
- restraint (seat belt) use;
- intersection safety;
- fatigue; and
- high risk groups (such as rural audiences and young male drivers; Cameron and Sullivan, 2011).

Evaluations of the SRSP have found that the use of advertising and enforcement, targeted at drink-driving, speeding and seatbelt use, was effective in reducing fatalities (by 285, over a five year period to June 2000; Guria and Leung, 2004) and serious casualties (between 1998 and 2010; Cameron and Sullivan, 2011), consistent with findings from other jurisdictions.

Young drivers (and particularly young male drivers) are disproportionately represented in road trauma, at least in part due to their greater likelihood of engaging in risky driving behaviours. The transition from learner to restricted licence, and restricted to full licence is associated with increases in the crash rate for drivers – as novice drivers are still gaining the ability to perceive hazards and navigate complex situations (Lewis-Evans, 2010; Weiss et al, 2014).

Graduated licensing systems, such as those in place in New Zealand, aim to provide novice drivers with the opportunity to gain experience, whilst limiting their exposure to higher-risk situations (such as accompanied by peer-group passengers or driving at night) that have been found to increase crash injury severity (Weiss et al, 2014). Other significant risk factors include seatbelt non-use, drink-driving, inexperience, fatigue and reckless driving behaviour – all of which can be influenced through public education and enforcement, and have complementary effects (Tay, 2005).

New Zealand Police have undertaken enforcement campaigns over high risk periods (such as December and January, called 'Safer Summer') in order to deter risky driving behaviour through lower speed enforcement thresholds and greater traffic enforcement intensity. An evaluation of this campaign found that there were significant decreases in the proportion of vehicles exceeding the speed limit during the campaign, relative to years where the campaign did not run (van Lamoen, 2014).

However, the effectiveness of public education and enforcement is indirect – in that it relies on these interventions to create awareness amongst road users and a deterrent effect, which influences behaviour, and in turn, impacts on crash risk and/or crash injury severity. These interventions need to be well designed and coordinated to ensure that their potential impacts are realised – and involve ongoing effort, to ensure awareness and behaviour change is maintained over time (Cameron and Sullivan, 2011).

2.2.5 Economic activity

Vehicle kilometres travelled acts as a measure of exposure to crashes, and is thought to be influenced by economic factors.

Conceptually, as general economic activity increases (e.g., as measured by falling unemployment) or factors affecting vehicle economics change (e.g., lower fuel prices), more kilometres may be travelled, increasing the level of exposure. However, increased economic activity may also lead to decreases in the risk of a casualty – through a lower average age of the vehicle fleet (and improved safety features), greater government funding for road safety interventions, or improved driver behaviour (IRTAD, 2015; Scuffham and Langley, 2002).

Scuffham and Langley (2002) found in their analysis of New Zealand road fatalities that increases in unemployment and decreases in real gross domestic product (GDP) were associated with a decrease in crashes in the short-term. Analysis by Elvik (2009) for 14 OECD countries found that two-thirds of the decline in fatalities during 2009 and 2010 were associated with the increase in unemployment in those countries over that period.

2.2.6 Weather, seasonality, and time of day

Poor weather conditions are, at first glance, thought to be associated with poorer road safety outcomes. However, Keall et al (2012) notes that the impact of poor weather on fatalities is not conceptually clear – bad weather could result in more difficult vehicle control, but also result in more careful

driving (as drivers adapt to the conditions), or fewer kilometres travelled (as individuals delay or cancel travel).

Seasonality (or month of year) is often used in modelling to approximate different average weather and travel patterns across a year (for instance, there may be greater travel by motorcycles in warmer months of the year). This approach has been used by Guria and Leung (2004), who found, with a series of quarterly indicator variables, that the October-December quarter was associated with a higher crash risk in New Zealand, coinciding with warmer weather. The time of day may also be associated with the risk or severity of a crash, as it relates to the likelihood of other risk factors (such as fatigue or drink-driving being present).

2.2.7 Number of overseas licence holders

New Zealand has a strong tourism industry, and with this, comes driving by overseas licence holders. An analysis of overseas driver crashes conducted by the Ministry of Transport (2016) found that approximately 6% of crashes involved an overseas licence holder, and of this, 77% are short-term visitors to New Zealand, between 2011 and 2015.

The prevalence of overseas drivers involved in crashes also varied by region, with a quarter of all crashes in tourist areas on the South Island involving an overseas driver. Approximately one third of at-fault overseas licence holders failed to adjust to New Zealand rules or conditions (Ministry of Transport, 2016). The failure to adapt to local rules may have been particularly notable in relation to the intersection "give way" rules in New Zealand up until 25 March 2012, when the rules were changed.

However, there is no reliable measure of the extent of driving or distances travelled by overseas licence holders, and thus the prevalence of crashes (and casualties) amongst overseas licence holders cannot be easily compared to those of domestic licence holders in order to determine whether being an overseas driver in New Zealand has a statistically significant impact on the likelihood of a crash, or the severity of a crash. Appendix D contains some descriptive analysis of crashes involving overseas licence holders and discussion of tourism trends in New Zealand.

Research from other jurisdictions suggests that whilst motor vehicle crashes are the most common cause of death or injury for tourists (followed by drowning), they remain a small proportion of the overall number of road fatalities (Wilks and Pendergast, 2010). The available analysis from Australia suggests that crashes involving international factors are no more (or less) likely to be the result of alcohol or speed than other crashes, but are more likely to be the result of problems such as:

- driving an unfamiliar vehicle in unfamiliar conditions (on the other side of the road and adapting to local rules);
- failure to wear seat belts; and
- driver fatigue due to underestimation of driving distances and times (Watson et al, 2004).

2.3 Broader contextual factors that might be changing the nature of these relationships over time

There may also be broader trends that have impacted the nature of relationships historically observed in the data and literature, and may not have been the subject of New Zealand-specific research.

These factors could include the impact of:

- changing **media consumption habits** (that is, the increasing use of streaming video services and social media) and the effectiveness of advertising on those media and ability to reach high risk groups, both overall, and relative to traditional advertising channels such as television – with research suggesting that online advertising has to be increasingly targeted and use obtrusive elements in order to attract viewer attention (Goldfarb and Tucker, 2011; Dreze and Hussherr, 2003);
- the increasing **prevalence of mobile phones** may have on driver distractions, and their perception of the risk posed by such distractions, Hallett et al (2011) found, through a survey of New Zealand drivers, that more than 60% of respondents had conversed on their phone whilst driving in the past week, and that 38% of respondents felt that this behaviour was 'moderately safe', despite the academic literature suggesting otherwise; and pedestrians using mobile phones are more likely to walk slowly, change directions more often, and are less likely to acknowledge other individuals or stimuli (Hyman et al, 2010). Some descriptive analysis of distractions as a factor in crashes are included in Appendix D;
- an **ageing population and pedestrian incidents** may have on crash severity – with Li et al (2003) finding that fragility (defined as risk of death, given involvement in a crash) began increasing at age 60, and appeared to be the key driver of increased fatality per unit of exposure for older drivers;
- increasing **sharing of roads with cyclists** may have on crash likelihood and severity, with an Australian study finding that the number of serious cyclist injuries has coincided with participation in cycling, and that cyclist visibility and driver awareness of cyclists is a key risk factor (Johnson et al, 2010) and New Zealand data suggesting that the injury rate for cyclists in New Zealand is second only to motorcyclists and has risen over time (Tin et al, 2009);
- changes in **second-hand vehicle importation laws** and regulations may have on the composition of the New Zealand vehicle fleet – with analysis showing that the crashworthiness of used imports, by first year of registration improved between 1986 and 2014, but that used imports brought into the New Zealand fleet in a given year are less crashworthy than new vehicles entering the fleet, and given that the average of used imports is increasing, this will likely increase the safety features gap over time (Newstead et al, 2016; and
- increasing **road congestion** may have on the nature of crashes that occur – with Marchesini and Weijermars' 2010 review of the literature suggesting that speed variability increases the likelihood of crashes (but that the impact on crash severity is mixed) and that unstable traffic flow conditions are more likely to lead to rear-end crashes and multi-vehicle crashes.

3 Modelling approach and results

This chapter outlines the data used, modelling approach and results of the econometric analysis, to understand the factors that have influenced the New Zealand road toll over the last 15 to 20 years.

3.1 Approach

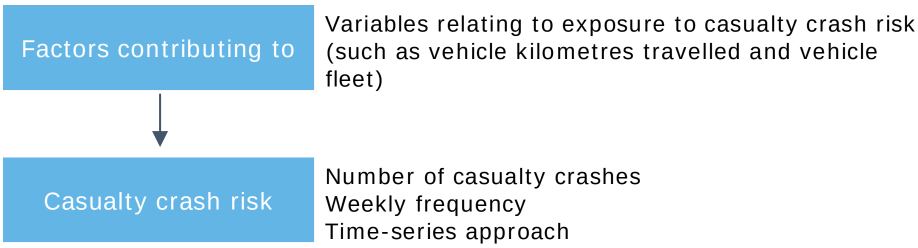
The purpose of the modelling is to understand the factors driving changes in the number of casualty crashes over time, the injury severity of those casualty crashes, and the extent to which the characteristics of casualty crashes has changed over time.

This analysis is comprised of three main components, which are outlined here, and brings together contemporary empirical approaches in the literature[6]. In particular, the separate modelling of crash likelihood and crash severity, and exploration of casualty-level data, is conducted to further disentangle severity outcome risk factors and allow for the consideration of differences in the relationships across crash risk and severity. The approach is described in greater detail in Appendix B.

Exploring number of casualty crashes

The first component of the econometric modelling seeks to understand the factors that are associated with variation in the number of casualty crashes over time.

This analysis departs from similar time series approaches in modelling the number of casualty crashes at a weekly (rather than monthly or quarterly) level. Increasing the frequency of analysis allows for modelling to capture more fine-grained variation in the relationship between the number of casualty crashes and relevant explanatory variables.



Exploring crash injury severity

The second and third components of the modelling seek to examine, from a macro perspective (Approach A) and a micro perspective (Approach B) the factors driving variations in crash severity, given that a casualty crash has occurred.

	Approach A	Approach B
	Better captures longer-term drivers of the	*Better captures the crash-specific*

[6] In particular, the statistical approaches employed by Kockelman and Kweon (2002), Weiss et al (2014), and O'Donnell and Connor (1996).

	severity rate, and how those drivers may have changed over time	*characteristics of interest*
Factors contributing to	Variables relating to the **system** (roads, road users, vehicles, speeds)	Characteristics relating to the **crash** (roads, road users, vehicles, speeds)
Crash severity, given casualty crash has occurred	Number of severe, fatal casualty crashes Weekly frequency Time-series approach	Probability that an injury is minor, severe or fatal Unit records Micro-econometric approach

Extent to which the characteristics of fatal crashes have changed since 2013 (Counterfactual analysis)
The final component of the analysis seeks to uncover the extent to which the nature of fatalities that have occurred in 2014 and 2015 have systematically differed from those up to 2013, and whether those changes are related to observed or unobserved factors.

Counterfactual analysis (changes in fatal crash characteristics)	Using the results of Approach B, to understand the extent to which the characteristics of casualty crashes have changed, through a comparison of actual and model-predicted fatalities

The approach to specifying each model was consistent and systematic, and involved the following steps (which are described in detail in Appendix B):

1. Identify the form of the equation, as determined by the statistical distribution and estimation method
2. Determine the appropriate explanatory variables to include in the model, through significance testing and those identified to be most likely to be important factors through the literature review
3. Ensure the robustness of the specification through testing

Taken together, these approaches allow for a systematic identification of the factors that drive the number of crashes occurring over time, and the severity of those crashes (both over time, and in relation to the characteristics of individuals involved).

3.2 Descriptive statistics

Data for this project was collected from the following sources:

- Ministry of Transport,
- New Zealand Transport Agency,
- New Zealand Police,
- Ministry of Business,
- Innovation and Employment, and
- Statistics New Zealand.

A key component of the analysis, prior to commencing modelling, was to examine descriptive statistics of the data. This process serves to identify key relationships between the variables of interest, and in particular the relationship between casualty crashes and the available explanatory variables. This step also provided an additional level of confidence in the

modelling by ensuring that was sufficient variation in the data to provide reliable modelling results.

Descriptive statistics of the casualty crash data revealed strong differences across a number of crash-related characteristics (such as injury severity, vehicle type, gender and age, and factors contributing to a crash, amongst others), and that the patterns of crashes varied across groups.

The descriptive statistics for other explanatory variables further illustrated that there were readily observable and intuitive trends over time in the data, which could be analysed through econometric modelling.

Detailed descriptive statistics are presented in Appendix A.

3.3 Results and Discussion

This section presents the main results of the econometric modelling and discusses some of the key findings. Full results are included in Appendix C.

3.3.1 Number of casualty crashes

The first set of modelling undertaken seeks to understand the drivers of the number of casualty crashes observed in New Zealand over time.

Following the approach outlined above, the modelling estimates the impact that a 1% increase in each of the explanatory variables has on the number of crashes (in percentage terms) observed in a given week. For example, a 1% increase in VKT is associated with a 2.5% increase in the number of crashes. These estimates are presented in Table 3.1 below.

Table 3.1 : Number of casualty crashes coefficient estimates

Variable	Estimate
Log VKT	2.522***
Log motorbikes	1.585***
Log enforcement	0.067**
Log-lag enforcement	-0.0990***
Lag proportion speeding	-1.0845**
52nd lag	-0.148***
N	614
R^2	66.06%

Source: Deloitte Access Economics (2016). Note: Statistical significance at the 10%, 5%, and 1% are represented by *, **, and ***, respectively. N represents the number of weeks included in the modelling, R^2 is a measure of model fit (the extent to which the included variables explain the variation in the number of crashes each week). The final specification of the model only includes the variables found to statistically significantly improve the model fit (and are all listed in the table above). Other potential explanatory variables were tested, but found to have no statistically significant explanatory power. Variables are log (logarithm) transformed in order to satisfy statistical assumptions of the model, and for ease of interpretation of the results.

The results presented above suggest that crash risk is strongly influenced to vehicle kilometres travelled (VKT) – as a 1% increase in VKT is associated with a greater than 1% increase in the number of crashes. It is important to note that these associations (and all associations found in this study) relate to the variation in the number of crashes over the full time period of analysis – not any individual week or year.

A 1% increase in number of motorcycle registrations is also associated with a greater than proportional (1.6% increase) in the number of crashes − which may be the result of the relative vulnerability − which are less visible to other road users and less stable (Ministry of Transport, 2015).

Contemporaneous enforcement (total infringements issued[7]) is associated with a small increase in the number of crashes (a 1% increase in enforcement in this this period is associated with a 0.07% increase in the number of crashes) − however, this may be related to the fact that police activity is targeted at times of the year and locations of higher crash risk (resulting in greater detection being associated with more crashes).

The lagged enforcement effect suggests that enforcement activity in the previous period decreases the number of crashes in the current period (suggesting that there is a deterrent effect occurring, with a 1% increase in enforcement in previous time periods associated with a 0.1% decrease in the number of crashes − and, taken together, suggesting that increases in enforcement activity, over time, are associated with decreases in the number of crashes).

Similarly, the proportion of vehicles recorded speeding over the posted limit (through mobile and fixed cameras) in previous periods is associated with a decrease in the number of crashes, again suggesting the existence of a deterrent effect (that occurs as the result of visible operations, or the receipt of an infringement notice).[8] Risk-weighted speed detections were also tested (following the approach of Kloeden et al, 2002), but were not found to be significant.

Modelling revealed that general (unexplained) trends in the number of casualty crashes over time plays a substantial role. Chart 3.1 illustrates the estimated annual time period effect in the model. It shows that there is a strong downward trend in the number of crashes occurring, over time. That is, there are unobserved factors not explicitly captured by the model that are decreasing crash risk over time.

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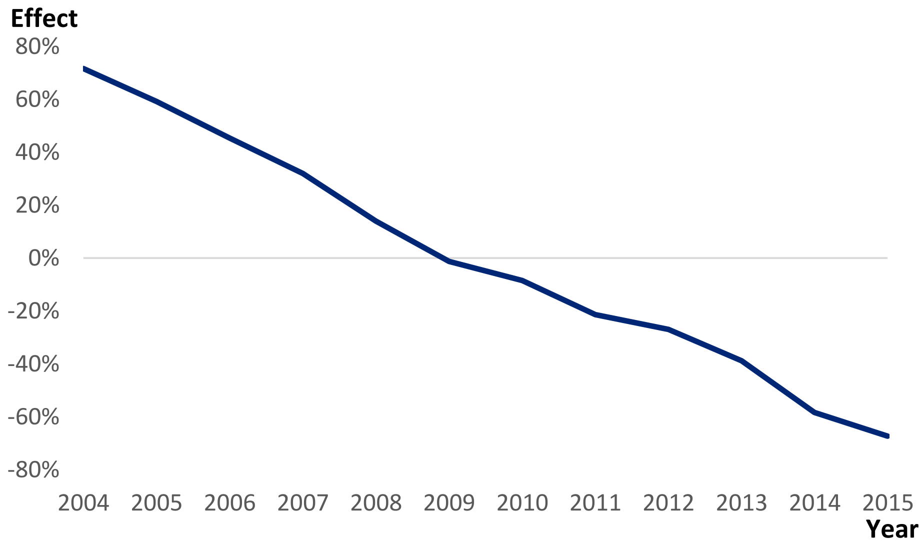
[7] Infringements relating to speeding, alcohol and drugs, restraint use and other categories were also tested as separate variables in the modelling, but were not found to be significant.

[8] A lag length of 10 was chosen based on magnitude and statistical significance. Testing revealed that the estimated effect was significant between lags 7 and 12, with no significant variation in its magnitude.

Chart 3.1 Year trend estimates



Source: Deloitte Access Economics (2016). Note: the sum of coefficients has been normalised to zero[9]. Each year is included in the model as a dummy variable (1 or 0) to capture any year-specific effects.

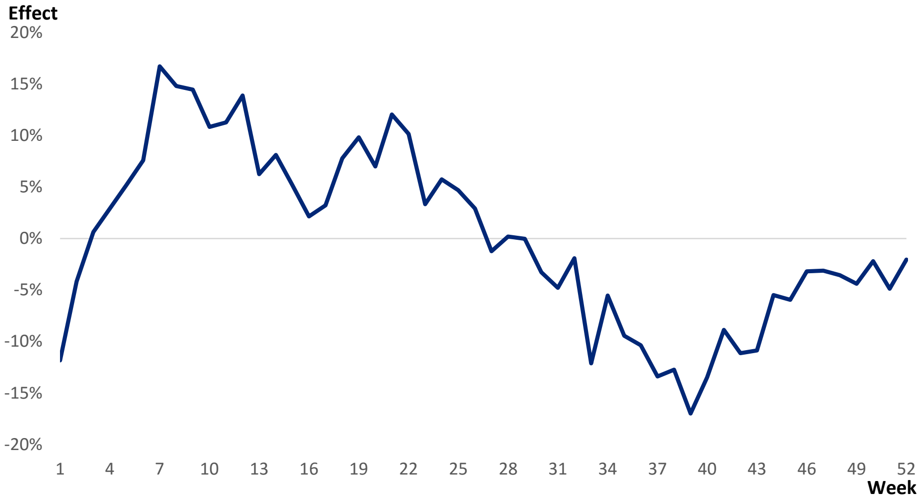
Together these results show that **despite the continued downward trend** in the number of crashes (as captured by Chart 3.2), there has been an **increase in the number of crashes in 2014 and 2015, which is closely related to increases in VKT, and number of registered motorcycles** (as shown in Table 3.1).

Chart 3.2shows the average effect that time of the year (as measured through week of the year dummies in the modelling) has on variation in the number of crashes over the time period, in addition to variables already controlled for.

The results suggest that the week-on-week variation in the number of crashes can, in part, be attributed to the time of year which is itself related to other factors that are unable to be sufficiently captured through some of the independent variables here.

[9] Normalisation procedure from Haisken-DeNew and Schmidt (1997).

Chart 3.2 Week of the year estimates



Source: Deloitte Access Economics (2016). Note: the sum of coefficients has been normalised to zero[10]. Each week of the year is included in the model as a dummy variable (1 or 0) to capture any week-specific effects. The first week of the year includes January 1.

Overall, the model performs relatively well, explaining around two thirds of the total variation in the weekly number of casualty crashes. Nevertheless, the remaining one third of variation in casualty crashes over time is not explained by the model. This likely reflects the reasonably large role that randomness plays in determining whether a casualty crash occurs, consistent with other findings in the literature (Nicholson 1985, 1986 and discussed in more detail in Section 3.3.4).

This is not to say that there are no other factors (beyond those described here) that are associated with the number of casualty crashes that occur each week. The effect of some of these factors (such as improvements in vehicle safety and road infrastructure, which shift slowly over time, and are difficult to statistically isolate) are likely to be captured in the long-term trend, whilst others may be currently unobserved (due to the limitations of the available data). As such, the limits of the analysis that can be undertaken and conclusions that can be drawn with the currently available data are being reached.

3.3.2 Crash injury severity, given a casualty crash (time-series approach)

In order to further understand whether system level factors had an influence on the changes in the road toll over time, models were run on weekly time series of serious and fatal casualty crashes[11].

In order to account for the strong relationship between the total number of casualty crashes and the number of serious injuries and fatalities, modelling was performed on the *rate* of injury severity per casualty crash. For example, modelling results refer to movements in the number of serious injuries per 100 casualty crashes.

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[10] Normalisation procedure from Haisken-DeNew and Schmidt (1995).
[11] Where the most severe injury in the crash defines whether the crash is serious or fatal.

Similarly to the previous section, the results can be interpreted as the impact of a 1% increase in an explanatory variable on the number of serious and fatal casualty crashes in a given week, in percentage terms. The results of this analysis is shown in Table 3.2.

Table 3.2 Crash severity, given a casualty crash has occurred, time series coefficient estimates

Variable	Serious injury	Fatality
Log VKT	2.899***	1.942***
Log motorbikes	-0.613*	
Lag-log advertising spend	-0.0723**	
Lag proportion speeding	-1.182*	
Log fuel price		-0.422***
Week 52	0.090*	0.352***
N	618	608

Source: Deloitte Access Economics (2016). Note: Statistical significance at the 10%, 5%, and 1% are represented by *, **, and ***, respectively. N represents the number of weeks included in the modelling. The final specification of the model only includes the variables found to statistically significantly improve the model fit (and are all listed in the table above). Other potential explanatory variables were tested, but found to have no statistically significant explanatory power. The number of observations for serious injury and fatality are not equal, as there are a number of weeks where no fatalities occurred. Variables are log (logarithm) transformed in order to satisfy statistical assumptions of the model, and for ease of interpretation of the results.

The results show that increases in VKT, beyond their impact on the number of crashes, also have an impact on the severity of a crash, such that a 1% increase in VKT is associated with a 2.9% increase in the number of serious casualty crashes (given that a casualty crash has occurred), and a 1.9% increase in the number of fatal crashes (given that a casualty crash has occurred).

This could be the result of some VKT associated with higher risk conditions (for example, travel on high speed or rural roads, different vehicle types or higher risk drivers) – however, further research is required to understand different types of risk associated with VKT and the nature of discretionary travel.

Contrary to its impact on the number of crashes, a 1% increase in the number of motorcycle registrations is associated with a 0.6% decrease in the serious casualty crash rate and is not found to be significantly related to fatal crashes, given that a casualty crash has occurred.

A 1% increase in advertising expenditure four weeks earlier is found to be associated with a 0.07% decrease in the number of serious crashes, given that a casualty crash has occurred. This lag can be thought to relate to a delay in the time taken for advertising to translate into awareness and changes in attitudes and behaviours.

The proportion of vehicles detected speeding (by cameras) six weeks earlier is associated with a decrease in the number of serious crashes (a 1% increase in detections is associated with a 1.2% decrease in the number of serious crashes, given that a casualty crash has occurred). This lag may be associated with delays in the receipt of speeding infringement notices (and

thus delays in the deterrent effect being observed), and points to the effect of enforcement on crash outcomes.

Increases in fuel prices are found to be associated with decreases fatal crashes, whilst a crash occurring in the last week of the year (week 52) was positively associated with serious injury and fatal crashes.

Controlling for the total number of casualty crashes substantially reduces the remaining systematic variation in the number of serious injury and fatal crashes. However, the results presented above suggest that there are consistent trends in the relationship between explanatory variables and the rate of serious injury and fatality crashes per casualty crash.

3.3.3 Casualty injury severity, given a casualty crash (micro-econometric approach)

Following the time-series analysis undertaken, micro-econometric analysis was undertaken using the CAS data, in order to capitalise on the detail contained within the unit record data files, which relate to all injured persons involved in a casualty crash. Uninjured persons are excluded from the analysis, as they are inconsistently recorded in the CAS data.

Results from the micro-econometric modelling are presented as marginal effects. They refer to the average change in the likelihood of being injured to a given level of severity resulting from an individual having that risk factor. For example, being in a motorcycle as opposed to a car increases the individual's risk that the casualty crash will lead to a fatality by 2.8 percentage points.

Table 3.3 presents an abbreviated set of calculated marginal effects from the estimates of the model, with full regression results and marginal effects presented in Appendix C. The most notable results being:

- being a motorcyclist, cyclist or pedestrian greatly increases the risk of a severe or fatal injury relative to an individual travelling in a car, reflecting the relative fragility and vulnerability of these road users;
- casualty crashes where alcohol or drugs, or inappropriate speeds were a contributing factor are also more likely to result in severe or fatal injury, reflecting the effects of impairment and high speed crashes, respectively; and
- casualty crashes on rural state highways and other open roads (which are more likely to be single carriageway and have fewer safety barriers installed) are more likely to result in severe or fatal injury, relative to crashes on minor urban roads, capturing the more severe consequences of high speed crashes.

Table 3.3 : Crash severity model (all injured persons) marginal effects, given that a casualty crash has occurred

Variable	Relative to	Severe injury likelihood (relative to minor injury)	Fatal injury likelihood (relative to minor injury)	Comment
Motorcyclists	Travelling in car	20.5 percentage points	2.8 percentage points	Relative fragility and vulnerability of these road users
Pedestrians	Travelling in car	28.9 percentage points	11.2 percentage points	
Cyclists	Travelling in car	24.7 percentage points	6.5 percentage points	
Travelling in truck, SUV or bus	Travelling in car	-0.4 to -2.3 percentage points	-0.2 to -1.8 percentage points	Mass differentials across the vehicle fleet
Alcohol or drugs	Other crash factors	5.9 percentage points	1.9 percentage points	Effects of impairment
Inappropriate speed	Other crash factors	2.7 percentage points	1.4 percentage points	Consequences of high speed crashes
≥ 100m/h speed zone	50km/h to 70km/h speed zone	2.0 percentage points	0.7 percentage points	Consequences of high speed crashes
State highways (rural) and other open roads	Minor urban roads	2.6 to 3.4 percentage points	1.0 to 2.1 percentage points	Capturing more severe consequences of high speed crashes (where there may be fewer safety features built into the road)
Male driver involved in crash	No male drivers involved in crash	1.2 percentage points	0.9 percentage points	Likelihood of males to engage in more-injurious driving behaviours
Restricted or learner licence driver	Full licence driver	-0.1 to 0.5 percentage points	-0.1 percentage points	Inexperience of new drivers and their relative ability to perceive high-threat hazards and adapt to changing road conditions
Two vehicle crashes	Single vehicle crash	-1.3 percentage points	-0.2 percentage points	Nature of two vehicle crashes

Source: Deloitte Access Economics (2016). Note: these results should be interpreted as marginal change in the probability of a given level of crash severity, **conditional on getting in a crash that involves at least one injury**. The marginal effects sum to zero across the three injury levels. N = 259,892. Time period = 1995-2015. Standard errors are clustered at the crash level. There are a number of other variables included in the analysis, but are not presented here because they were either not significant (e.g. individual role in the crash), or acted as control variables (e.g. year dummies).

A number of other factors were found to be statistically significant determinants of crash injury severity, and are presented in Appendix C.

The local government region results suggest that there is a greater likelihood of a severe injury occurring (relative to a minor injury) if the crash occurs in a region other than Auckland – with the greatest differences in the Otago (4.9 percentage points), Southland (4.2 percentage points) and West Coast (3.5 percentage points) regions. Results for the likelihood of a fatality were mixed across local government regions.

This could be the result of systematic differences across these regions in road infrastructure, vehicles in these regions, or road user (characteristics or behaviours) that are not explicitly captured in the variables that have been included in the modelling – however there is incomplete information available about how these factors might differ across regions, making it difficult to draw meaningful conclusions about the drivers of these results.

Variables that were not found to be statistically significant (such as whether a distraction was a contributing factor to the accident, or whether the individual was a driver or passenger) were included in the final specification.

Overall, these findings reinforce that there are a variety of severity risk factors relating to the characteristics of a crash, which could be monitored and targeted through road safety interventions (discussed in Chapter 4).

3.3.4 Counterfactual analysis (changes in fatal crash characteristics)

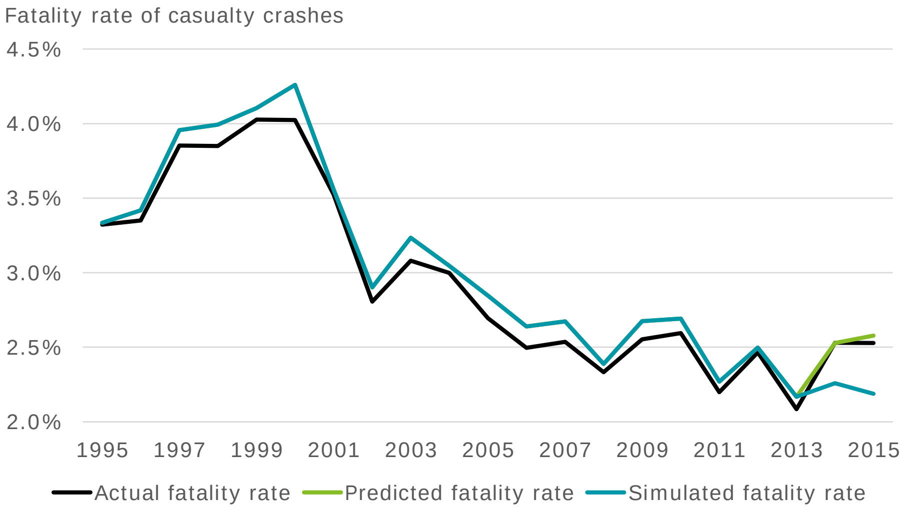
Further analysis was then undertaken to understand the counterfactual scenario for the period of interest (2014 and 2015). This seeks to answer the question, "What would the fatality rate have been if the external conditions driving the dip in fatalities in 2013 were applied to 2014 and 2015?" The results from this exercise decompose the fatality rate in to three components:

- Characteristics of crashes
- Annual trends in the severity of crashes
- Unexplained ('random') fluctuations in crash risk severity

This decomposition is provided in Chart 3.4, which illustrates:

- Actual fatality rate (black line);
- Predicted fatality rate (green line)
  - Which removes the unexplained component of fluctuations from the Actual fatality rate
- Simulated fatality rate (blue line)
  Which applies the average 2013 fatality risk to 2014 and 2015

Chart 3.3 Counterfactual analysis of the fatality rate



Source: Deloitte Access Economics (2016).

The chart shows that if the characteristics of the crash were driving the increases in fatalities in 2014 and 2015, the simulated fatality rate line would have more closely tracked the predicted fatality rate line – however as it does not, the conclusion drawn is that:

- the increases in fatalities observed in 2014 and 2015 are unlikely to be the result of factors relating to observable characteristics of the crash (such as the road type, vehicle type or licence status) – but rather to other broader trends such as changes in vehicle kilometres travelled, and unobserved factors.
- This is because the simulation is based on the known characteristics of fatalities in 2013, not the unknown factors that were present in 2014 and 2015.

Essentially, this implies that the historically low number of fatalities in 2013 was an abnormal year – driven by broader, unobserved factors and trends, rather than the result of some systematic change in the nature of crashes themselves. This result also implies that, to an extent the increases in fatalities in 2014 and 2015 represented a reversion to the longer-term trend.

This aligns with existing findings (Nicholson 1985, 1986), which suggest that there is a component of 'chance' to road trauma, given the way in which the frequency of crashes changes each year, and the statistical properties and distribution of road trauma[12] – which may account for the unexplainably low road toll years.

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[12] Broadly following a Poisson distribution, if all other factors affecting crash risk are largely constant. More discussion of Poisson distributions are included in the appendices. Direct comparisons of the extent to which variations in road trauma are unexplained across different studies is not possible, given the different modelling techniques and data variables used.

Looking to 2016[13], the provisional road toll stands at 328, an increase of 2.8% over the previous year, and 1,425 serious injuries between January and July 2016, compared to 1,199 for the same months of 2015 (a 18.8% increase) − despite there being fewer crashes in total (5,372 between January and July 2016, compared to 5,795 for the same months in 2015).

These continued increases in road trauma highlight the need and imperative for there to be continued research and data collection (which are described in greater detail in the following chapter) − to further develop the understanding of the factors driving road trauma.

3.3.5 Comparison to previous studies

Several previous studies have explored the drivers of road fatalities in New Zealand, in particular analysing the 2011 reduction in road fatalities:

- An Analysis of Potential Factors behind the 2011 Reduction in New Zealand Road Fatalities (Keall et al., 2012)
- Econometric Analysis of the Downward Trend in Road Fatalities since 1990 (Infometrics, 2013a)
- Further Econometric Investigation of the 2011 Reduction in Road Fatalities (Infometrics, 2013b)

Based on an analysis of both short and longer term drivers of the number of road fatalities, these studies provide evidence to suggest that the reduction in 2011 is largely the result of "good luck". The estimated determinants of road fatalities do not account for the substantial reduction in road fatalities in 2011.

The econometric method used in this analysis aligns most closely with that undertaken by Keall et al. (2012) and Infometrics (2013b)[14]. Taking longer term trends as given, both sets of analyses explore the drivers of short term fluctuations in road trauma. However, the only common estimated variable is that of the number of motorcycle registrations, with all studies finding a significant positive relationship between motorcycle registrations and road trauma.[15]

However, there are a number of important differences between the results presented in this analysis and those previously undertaken in New Zealand that imply that the results are not directly comparable. Primarily, this study takes a top-down approach, modelling the *weekly number of casualty crashes*[16] and the *rate at which a casualty crash becomes a fatal crash*. This differs from Keall et al. (2012) and Infometrics (2013b), as both analyse the *quarterly number of fatalities*.

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[13] Data relating to 2016 road trauma has not been included in the modelling as complete data for all explanatory variables is not yet available.
[14] The approach taken in Infometrics (2013a) models the trend in fatalities (which is controlled for in this analysis through the use of yearly and weekly dummy variables), at an annual frequency. The Infometrics (2013a) method is less similar to the method used here, and as such, the discussion in this section largely focuses on the other two papers.
[15] Although not directly comparable, a relatively crude comparison of the relationship between motorcycle registrations in this study and Infometrics (2013b) suggests that a 1% increase in registrations in 2012 implies an increase in fatalities of 5.6 versus 15.1, respectively.
[16] Noting that the key results did not change if a monthly frequency was chosen instead.

This could lead to different results, as the number of fatalities will be affected by changes in both the fatality rate, as well as the number of individuals involved in a fatal crash. For example, holding the fatality rate constant, an increase in the number of fatalities could be driven by an increase in the number of vehicle occupants. In addition, there could be important factors at a higher frequency level (such as weekly or monthly) that are not observed at the quarterly level. This means that analysis of the quarterly number of fatalities could wash out important fluctuations (and drivers of those fluctuations) within the quarter.

Analysing the data at a weekly level reduces the influence of the trend on the estimates of other factors[17] and introduces relatively small counts, which implies that a log-linear specification is more appropriate (relative to specifying the relationship in levels). Although this changes the interpretation of the results, it is not expected to substantially change their magnitude or direction (a model of the number of casualty crashes in levels closely aligned with the log model).

Finally, a strong relationship between the number of casualty crashes and VKT was observed in this analysis. The omission of VKT as an explanatory factor could impact the conclusions of Keall et al. (2012) and Infometrics (2013b). However, results from this study suggest that VKT only influences the number of fatal crashes through the number of casualty crashes (that is, holding the fatality rate constant). As a result, the influence of the omission of VKT in previous studies will be confounded with the choice to model the number of fatalities, as opposed to the number of crashes resulting in at least one fatality per casualty crash. This means that, the effect of the omission of VKT on results presented in these two studies is unclear.

[17] That is, persistence.

4 Findings and implications

This chapter outlines the key findings from the econometric modelling, and their implications for the Ministry's ongoing monitoring of road safety and research agenda.

4.1 Key modelling findings

The key explanators of short term fluctuations are found in this modelling (and consistent with the literature) to be:

- An increase in the number of vehicle kilometres travelled (VKT).
  - The analysis suggests a more than one-for-one increase in the number of crashes (and the rate at which those crashes are severe) –which could imply that additional VKT is associated with higher risk travel.
- Increases in the number of motorcycle registrations.
  - This aligns with the relative vulnerability of motorcycles – which are less visible to other road users and less stable (Ministry of Transport, 2015).

In interpreting these findings, there is a need to be cognisant of the multi-variate approach that this analysis has taken – that is, there is no one single factor that can fully explain changes in the road toll. Whilst this analysis has helped to identify some of the key drivers and contributors – no one factor should be taken in isolation, to the exclusion of others, and should be tempered against the large component of the changes that remain unexplained.

Analysis of individual-level crash data identified a number of risk factors that were associated with increased probability of severe and fatal injury, given involvement in a casualty crash. Broadly, these findings affirmed what has been previously found in the literature from New Zealand and other jurisdictions – with male drivers, relative inexperience, speeding, alcohol and/or drug presence, and light vehicle types being key risk factors for more severe crash injury outcomes.

Confidence can be placed in these results, given the strength of the factors modelled in explaining the variation in the number of casualty crashes and the injury severity, and their alignment with findings in the literature and prior expectations. However, there is an ongoing imperative to improve the quality of data available for analysis, in order to further ensure that the results are robust and build the road safety evidence-base over time.

4.2 Implications for the Ministry's ongoing monitoring programme

The evidence-base for what road safety interventions are effective continues to be developed across a variety of contexts, in order to inform the ongoing design and evaluation of road safety policy, and understand progress towards the long-term vision of the *Safer Journeys* strategy. In addition, there remains a need to consider these effectiveness measures and findings alongside the economic and social costs associated with them.

An ongoing monitoring programme for the Ministry will provide important, evidence-based guidance as to which road user cohorts are at greatest risk of crashes and crash severity, areas where policy interventions are warranted, and are having an impact.

Table 4.1 outlines, at a high level, the factors that could be monitored, and how changes in them could be interpreted, particularly in relation to:

- how interventions could impact on factors found to be associated with crash likelihood and injury severity; and
- the changing relationship between these factors and road safety (i.e. breaking the link between risk factors and road trauma).

Table 4.1 Informing the ongoing monitoring framework

Potential intervention	Factor identified for monitoring through the modelling	Changes in factors expected to be observed, if intervention is successful	Current relationship with crash risk or injury severity
Safer roads			
Road infrastructure investment (to improve built-in safety features of the road)	Road type	Weaker relationship between road type and crash severity, as treatments to improve the safety of riskier roads take effect	Severe injury or fatality 1.0 to 3.4 p.p. more likely to occur on rural state highways or other open roads
	Vehicle kilometres travelled	Weaker relationship between VKT and the number of crashes, and their severity, as crash risk for a given unit of exposure decreases due to improved infrastructure	A 1% increase in VKT is associated with a 2.5% increase in the number of crashes
Investment to improve safety in for pedestrians	Pedestrians	Weaker relationship between pedestrians and crash risk and severity, as treatments improve the awareness of vehicles to pedestrians and reduce impact speeds	Severe injury or fatality 40.1 p.p. more likely to occur for pedestrians, relative to car occupants
Investment in cycling infrastructure (such as dedicated bicycle lanes)	Cyclists	Weaker relationship between cyclists and crash risk, as treatments improve the safety of cycling routes and increase separation of bicycles and motor vehicles	Severe injury or fatality 31.2 p.p. more likely to occur for cyclists, relative to car occupants
Safer speeds			
Enforcement activity Lowering of speed limits	Proportion of vehicles observed speeding[18]	Proportion of vehicles observed speeding decreases, as enforcement activity and lowered speed limits change behaviour	A 1% increase in proportion of vehicles observed speeding in the previous period is associated with a 1.1% decrease in the number of crashes

[18] Whilst the time-series modelling used a measure of the rate of sanctioning of speeding drivers, ongoing monitoring may prefer to rely on annual surveys undertaken by the Ministry of Transport, which is a more reliable measure of the proportion of speeding on the road.

Potential intervention	Factor identified for monitoring through the modelling	Changes in factors expected to be observed, if intervention is successful	Current relationship with crash risk or injury severity
	Speed as a contributing factor to crashes	Prevalence of speed as a contributing factor in crashes decreases, as enforcement activity and lowered speed limits change behaviour	Severe injury or fatality 4.1 p.p. more likely to occur where one of the vehicles in the crash was travelling at an inappropriate speed
Safer vehicles			
Introduction of new vehicle safety features (such as auto-emergency braking) into the vehicle fleet	Vehicle safety ratings (currently proxied by vehicle age)	Stronger relationship between vehicle safety and lower crash severity, as improved safety features penetrate the majority of the fleet over time	Severe injury or fatality 0.2 p.p. more likely to occur as vehicle age increases by 1 year
	Vehicle type	Reduced crash severity in instances where light and heavy vehicles are involved in a collision, as there are improved safety features	Severe injury or fatality 23.3 p.p. more likely to occur if the casualty was riding a motorcycle
Safer road users			
Road safety advertising	Factors contributing to crashes (alcohol and drugs, speeding, distractions)	Prevalence of these contributing factors in crashes decreases, as advertising (along with enforcement) educates drivers and creates attitudinal and behavioural changes	Severe injury or fatality 7.8 p.p. more likely to occur if alcohol or drugs was a contributing factor to the crash
	Motorcycle registrations	Weaker relationship between number of motorcycle registrations and number of crashes, as motorcyclists and other drivers are more aware of the risks	A 1% increase in motorcycle registrations is associated with a 1.6% increase in the number of crashes
Graduated licencing systems and driver training	Licence type	Weaker relationship between licence type (restricted or learner) and crash severity, as these drivers gain greater experience in lower-risk environments	Severe injury or fatality - 0.4 to 0.2 p.p. more likely to occur if the casualty holds a restricted or learner licence
	Gender	Weaker relationship between gender and crash severity, as greater education of the consequences of risky and highly-injurious behaviour lead to behavioural and attitudinal changes	Severe injury or fatality 0.6 p.p. more likely to occur if the casualty is male
	Young drivers	Weaker relationship between young drivers and crash severity, as they have more opportunities to gain skills in lower-risk environments	Severe injury or fatality 0.2 p.p. more likely to occur as casualty age increases by one year (from the average age)

Source: Deloitte Access Economics (2016)

There are also a number of factors identified in the modelling that had an impact on crash likelihood or crash injury severity that were not strictly

within the influence of road safety interventions (fuel prices, the number of vehicles involved in a crash, movement of vehicles involved in a crash, weather and lighting at a crash), but may still be worth monitoring, to understand whether other factors may be driving observed changes in road trauma.

This project has also reiterated the need to continually improve the quality of data that is being collected and evidence-base that is being developed, in order to:

- monitor trends and emerging issues;
- provide even greater confidence in the reliability of empirical relationships observed; and
- inform the design and evaluation of policy – by allowing policymakers to target interventions at the factors that matter – both as discrete investments, and as a complementary suite of investments.

Finally, beyond the impact of interventions on the road toll, it is also important to consider the costs associated with a policy as part of any evaluation or monitoring programme (both as they relate to government expenditure and costs to society more broadly, such as travel time increases). This will better ensure that a balanced view of investment prioritisation is taken, and that interventions with the greatest impact, subject to their costs, are implemented, in keeping with public welfare theory more broadly.

4.3 Considerations for future and ongoing research

This project has identified a range of opportunities for enhancements to support future analysis of the factors driving the road toll in New Zealand, as well as new areas of inquiry that could continue to be explored in keeping with social and technological change.

In particular, while the analysis was able to draw on a number of large and rich datasets, there are areas where improvements in **data availability, specificity and quality** could further enhance the explanatory power of the modelling and confidence in the results. These include:

- Improving the **collection of data relating to casualties over time** – greater accuracy, consistency and completeness in the variables within the dataset will create greater confidence in the data and any findings from it (and reduce the likelihood of spurious or biased results). In particular:
  - improving the quality and completeness of data relating to **drug-driving** as a factor contributing to crashes and injury outcomes (given concerns that it may currently be underreported, particularly where alcohol was also involved) and the level of detection, given the increased focus of road safety agencies on drug-driving education and enforcement;
  - improving the quality and completeness of data relating to **distractions** as a factor contributing to crashes and mobile phone use whilst driving, which is pertinent given broader contextual changes relating to their use that are being observed (see Section 2.3 and Appendix D.2); and
  - consideration to the collection of data with more **granular detail relating to injury severity** (using measures such as the Abbreviated Injury Scale) to allow for a more gradated definition of severe injury than the present CAS allows.

- Enhanced measures that capture the **impact of advertising** across all media channels on road user attitudes and behaviours, given changing media consumption habits. This could include greater use of existing and enhanced surveys of road users (for example, relating to alcohol and drug, and device use whilst driving).
- More historical data on **infrastructure investment** (at the site level) and type of infrastructure (maintenance versus safety features, as well the target road user group of treatments – i.e. vehicles, motorcyclists, cyclists and pedestrians) to allow for better integration into the model, and disentangling of its effects on road safety.
- Continuing to improve the frequency of **VKT** data and the level of granularity (regions, types of roads, vehicles, drivers and the extent to which it is discretionary) with which it is available, given the strength of its relationship with both the number of crashes and crash severity, to ensure that the empirical relationship is robust
- Data on the distances travelled by **overseas licence holders** (currently unavailable) would allow a greater understanding of the extent to which crash risk for these individuals systematically differs from the population as a whole, as well as the extent to which increased tourism has increased overseas licence holder driving (see Appendix D.1 for some preliminary analysis).
- Finally, improving the **frequency at which data is collected** and available for a number of explanatory variables (such as VKT, unemployment, and advertising expenditure) would reduce the need to interpolate monthly or quarterly variables to a weekly frequency, and thereby reduce the likelihood of bias in the results and allow a more granular interpretation of results.

Throughout the project, a number of **areas where research and inquiry should be continued or undertaken** were identified. For many of these research questions, more complete analysis and conclusions will be enabled by the improvement of existing and new data collections. These research questions included:

- Improving the understanding of how driving while impaired by **drugs** impacts on crash risk and injury severity, and whether drugs and alcohol have compounding impairment and injurious effects – and the attitudes and behaviours of road users in relation to drug-driving.
- Understanding high-risk locations for **cyclists and pedestrians** and the types of crashes that they are involved in, in order to better target interventions (particularly relating to improved infrastructure) that alleviate these risks.
- Understanding the manner in which **mobile phones and other devices** are being used whilst driving (and how attitudes towards their use are changing) can inform a deeper understanding of how these devices may influence crash risk, and appropriate policy interventions to counteract these trends.
- Investigating the way in which increases in **road congestion** (particularly in urban areas) may influence the types of crashes that occur, and the implications of that for crash severity.
- Improving the understanding of the crash risk associated with **different types of VKT** – to help disentangle region-specific or road-type-specific factors that may be driving the strong relationships found in this study.
- Exploring the **KiwiRAP star rating data**, which assesses the safety features of roads (such as horizontal alignment, shoulder width and roadside hazards), and their ability to protect a road user under three crash types (run-off road, head-on, and intersection)

    - As multiple years of star rating data become available, it will become possible to undertake more detailed analysis of whether improvements in a star rating at a given site can be linked to decreases in crash risk and severity (both in terms of personal risk and collective risk), and whether there are changes in the types of crashes occurring at those sites
- Understanding the impact of **location-specific road safety interventions** (such as variable speed limits at intersections or the installation of median barriers), thereby allowing the effectiveness of these treatments on road safety to be more comprehensively assessed
- Collation of data on **vehicle safety star ratings for older vehicles** would allow a more granular analysis of the crashworthiness and safety features of older cars in the fleet to be undertaken, and in turn, provide government with a deeper understanding of the trade-offs relating to used vehicle importation laws (and whether there is a case for increasing safety requirements of used vehicle imports)
    - Such a dataset would also provide consumers with greater information during the purchasing process about the relative safety features of different vehicles

In the end, there is a need to ensure that future and ongoing research builds the evidence-base for what road safety interventions work (and equally, what doesn't work) in reducing road trauma, to inform the continued refinement of the ongoing monitoring programme and future policy development.

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Appendix A : Descriptive statistics

The econometric modelling undertaken is based on data collected from the Ministry of Transport, New Zealand Transport Agency, New Zealand Police, Ministry of Business, Innovation and Employment, and Statistics New Zealand. A more detailed description of the scope of the data, the years for which it is available, and the unit and frequency of observation is included in Appendix B.

This section provides a summary of the descriptive statistics of the key variables that are included in the model or have informed the modelling approach, and allow correlations between key variables to be revealed.

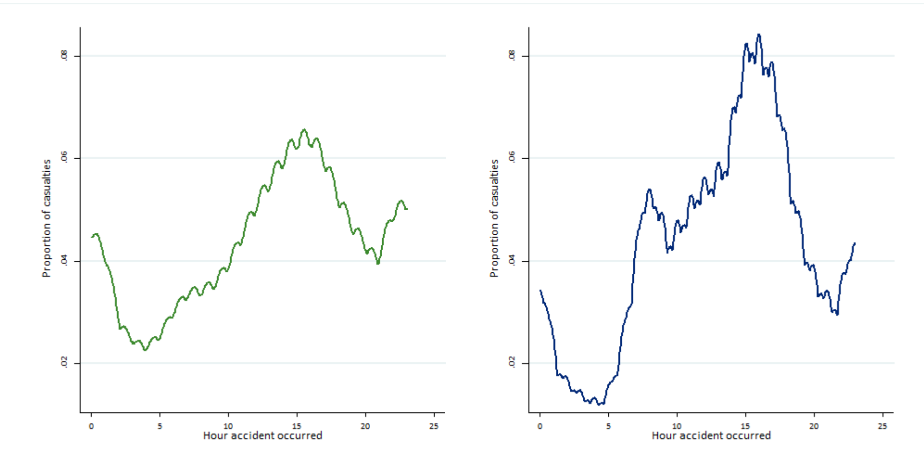
A.1. Stratification of models

The model will be stratified over a number of factors, in order to test whether different groups have different causal factors and relationships, in addition to a central case model.

Fatalities and injuries

Factors that contribute to crash injury severity, are not necessarily the same ones that contribute to crash likelihood. Chart A.1 shows that the profile of fatalities and injuries, by time of day varies – with proportionately more injuries occurring during the morning and afternoon peak hours, and proportionately more fatalities occurring in the evening peak and at night.

Chart A.1 All fatalities (LHS) and injuries (RHS), by time of day



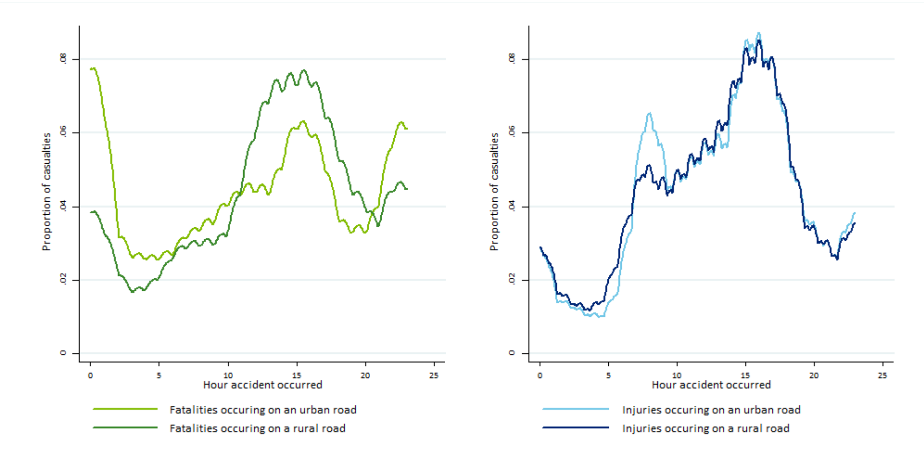
Source: CAS

Urban and rural roads

Travel on urban roads, which are defined as roads with a speed limit of 70 km/h or less, follow different patterns, levels of congestion and may involve different vehicle types to rural roads (defined as roads with a speed limit of greater than 70km/h). Chart A.2 shows that there are proportionately more injuries on urban roads during the morning peak hour (perhaps relating to higher traffic volumes, and hence greater exposure to crash risk, in urban

settings). Proportionately more fatalities happen on rural roads during the day, which is similarly likely to reflect travel patterns and behaviour.

Chart A.2 Fatalities (LHS) and injuries (RHS) on urban and rural roads, by time of day



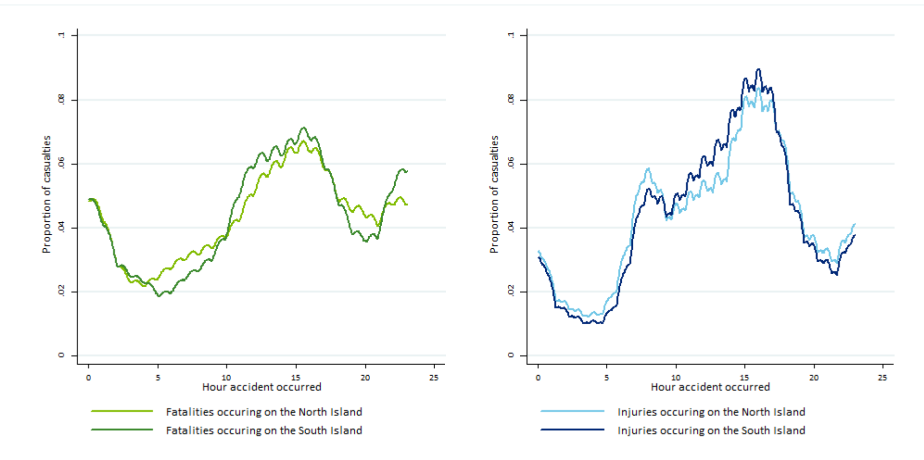
Source: CAS

The differences in patterns of road trauma between urban and rural roads may also reflect differences in the type of crash, broadly defined as whether a vehicle stays on the road or not during a crash.

North and South Islands

In contrast, the profile of fatalities and injuries on the North and South Island (Chart A.3), by time of day follow a similar distribution, suggesting that there may not be significant variation by island.

Chart A.3 Fatalities (LHS) and injuries (RHS) for North and South Island, by time of day



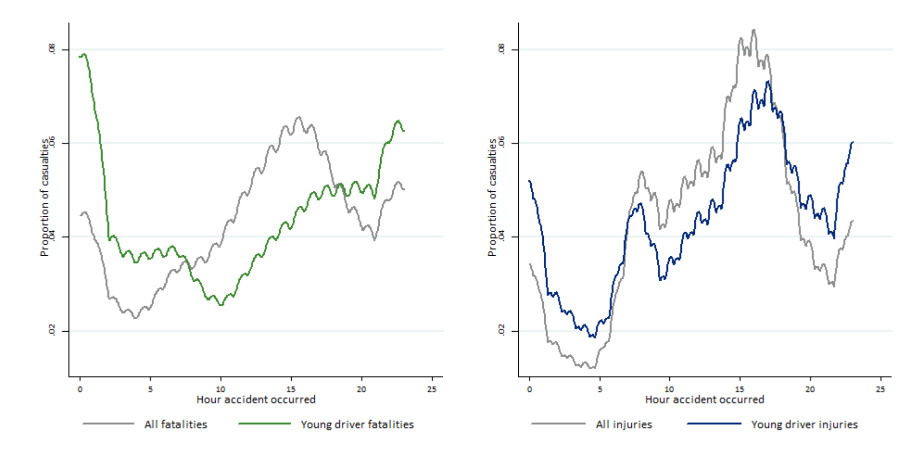
Source: CAS

Road user (or individual) type

The level of exposure, crash risk and injury severity may also vary by type of road user, with the literature having identified young drivers, older drivers, motorcyclists, cyclists and pedestrians as high risk groups.

Young drivers (aged under 25), are more likely to suffer a fatality or injury at night (Chart A.4) – and this may be linked to their travel patterns (and hence risk exposure) or the likelihood of them engaging in risky behaviour.

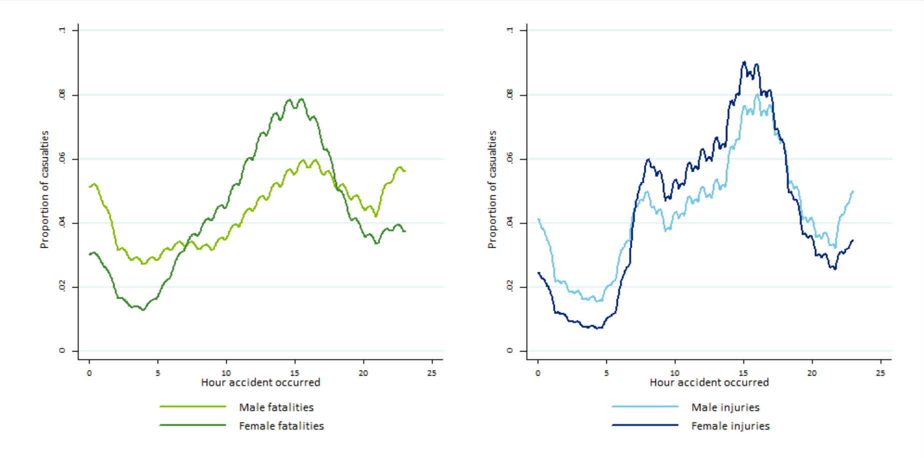
Chart A.4 Fatalities (LHS) and injuries (RHS) for young drivers, by time of day



Source: CAS

There are also variations when examining fatalities and injuries of young drivers by gender – with proportionately more males suffering fatalities and injuries at night, and the reverse during the day (Chart A.5).

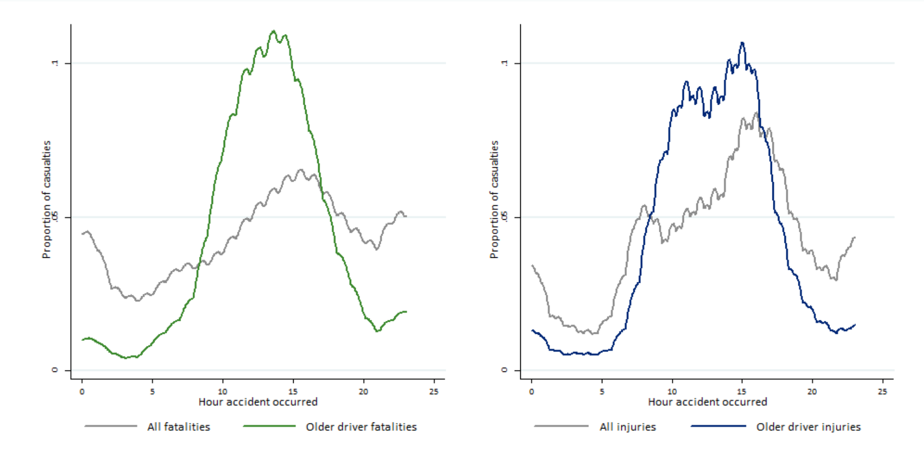
Chart A.5 Fatalities (LHS) and injuries (RHS) for young drivers, by gender and time of day



Source: CAS

Older drivers (aged 75 years and over) may be at greater risk of severe injury in a crash, given their fragility, and have different travel patterns to the broader population, which is reflected in the clustering of both fatalities and injuries to daytime hours (Chart A.7).

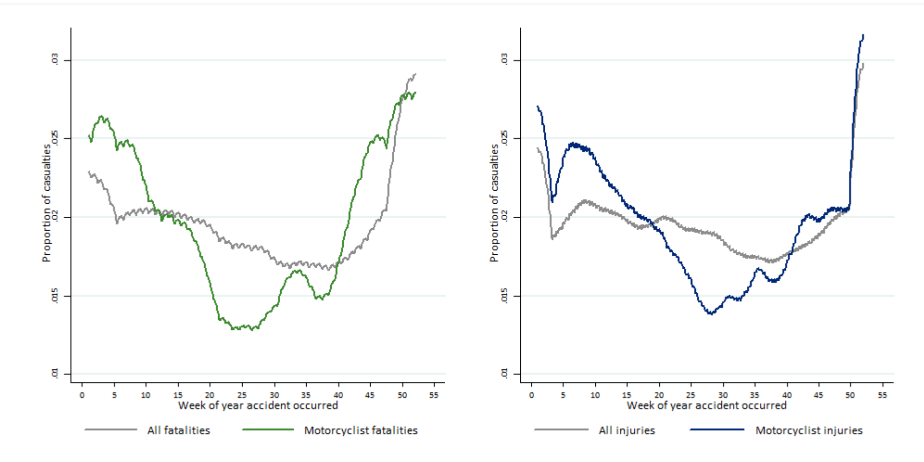
Chart A.6 Fatalities (LHS) and injuries (RHS) for older drivers, by time of day



Source: CAS

Motorcyclists are more likely to suffer road trauma during the day, and during the warmer months of the year (Chart A.6). This is again likely to be related to their travel patterns – indeed, motorcycle registrations in New Zealand are available on a monthly basis, and there are significantly more motorcycles registered in summer months (ranging from 58,000 on average in July, to 71,000 on average in January, between 2000 and 2016).

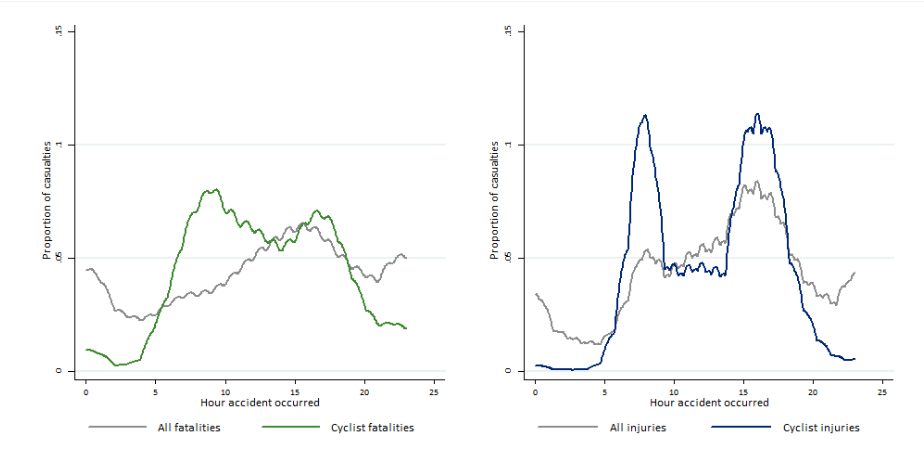
Chart A.7 Fatalities (LHS) and injuries (RHS) for motorcyclists, by week of the year



Source: CAS

Cyclists are likewise vulnerable road users (Chart A.8), and there are two significant peaks in the distribution of injuries by time of day – during the morning and afternoon peak. This could reflect the increased volumes of bicycle travel at these times of the day, for those commuting to work, and increased levels of road congestion during these times. This can be contrasted against the distribution of fatalities, which is also bi-modal, but to a much lesser extent.

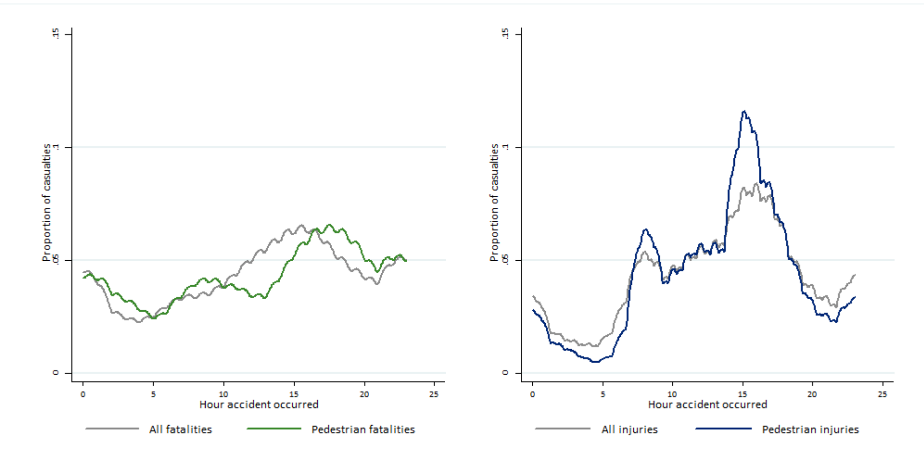
Chart A.8 Fatalities (LHS) and injuries (RHS) for cyclists, by time of day



Source: CAS

Pedestrians similarly have two peaks in the distribution of injuries by time of day (Chart A.9), around the morning and afternoon peak – which could reflect the volume of pedestrians commuting to work or school at those times of days. Beyond this, the factors that contribute to pedestrian road trauma may systematically vary from those of other road users, as they are not travelling in a vehicle.

Chart A.9 Fatalities (LHS) and injuries (RHS) for pedestrians, by time of day



Source: CAS

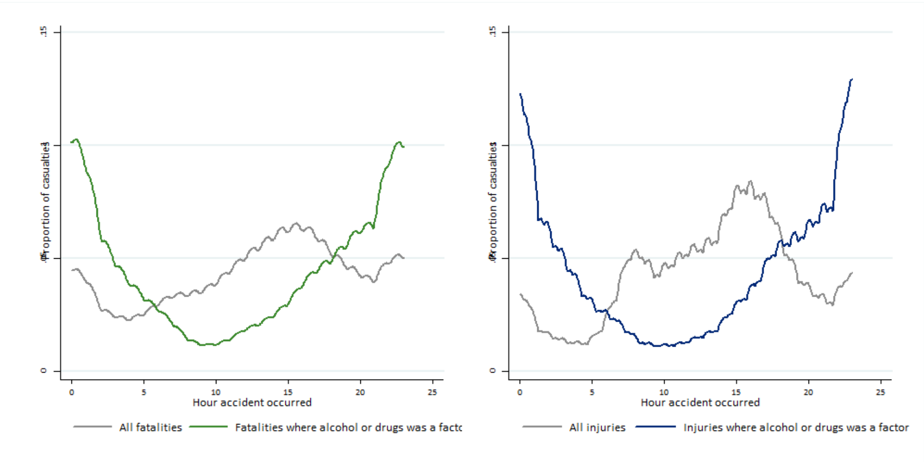
Factors likely to contribute to crashes

Relationships between crashes and causes may systematically differ by their contributing factor. This factor is recorded in CAS based on the information provided by a police officer attending a scene.

Fatalities and injuries where alcohol or drugs was a contributing factor are presented by time of day in Chart A.10. Alcohol and drugs are a much more common factor at night than during the day, impairing judgement and likely increasing crash risk.

Whilst it would be ideal to be able to separately model the contribution of alcohol and drugs (and indeed there are separate codes in the system), the recording of drugs as a contributing factor is not systematic. This is because when alcohol is found as a contributing cause, further investigation into driver culpability (due to impairment from drugs) is considered unnecessary – even if an individual is indeed under the influence of multiple substances. In addition, drugs must be shown to have caused impairment, unlike alcohol, where only an illegal blood alcohol level must be shown.

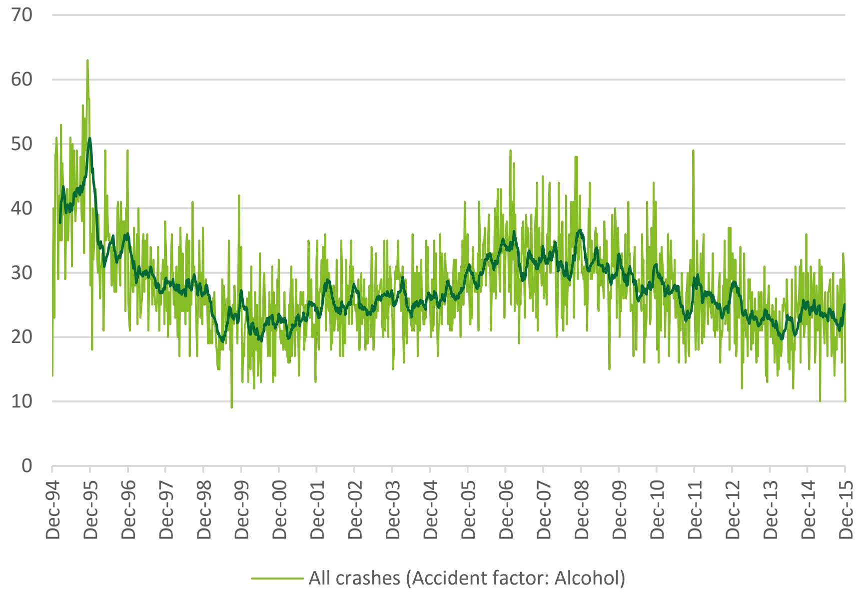
Chart A.10 Fatalities (LHS) and injuries (RHS) where alcohol or drugs was a contributing factor to the crash, by time of day



Source: CAS

The number of crashes where alcohol was a contributing factor has tended to decrease over recent years (Chart A.11), although there was a peak from 2006 to 2008.

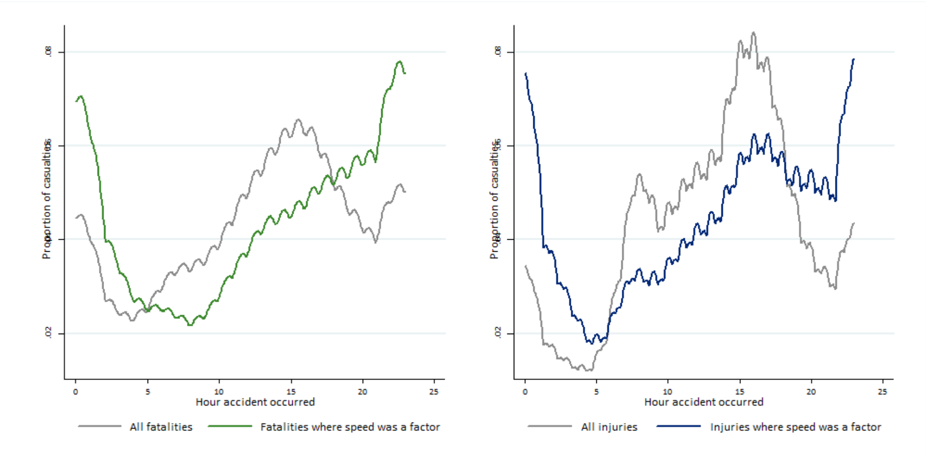
Chart A.11 All crashes where alcohol was a contributing factor, (weekly, with 12 week moving average, 1995-2015)



Source: CAS. Note: the dark green line represents the twelve week moving average of the number of crashes – and is shown to smooth out weekly variability.

Speeding (defined as travelling too fast for the conditions, not necessarily exceeding the speed limit) can lead to increased crash likelihood and injury severity – and fatalities and injuries where speed was a contributing factor are more likely to occur during the night (Chart A.12), with a small spike, in injuries during the evening peak hours. This pattern of casualty could relate to the level of congestion on the roads, particularly relevant in urban settings, where lower speeds mean that crashes are likely to be less severe.

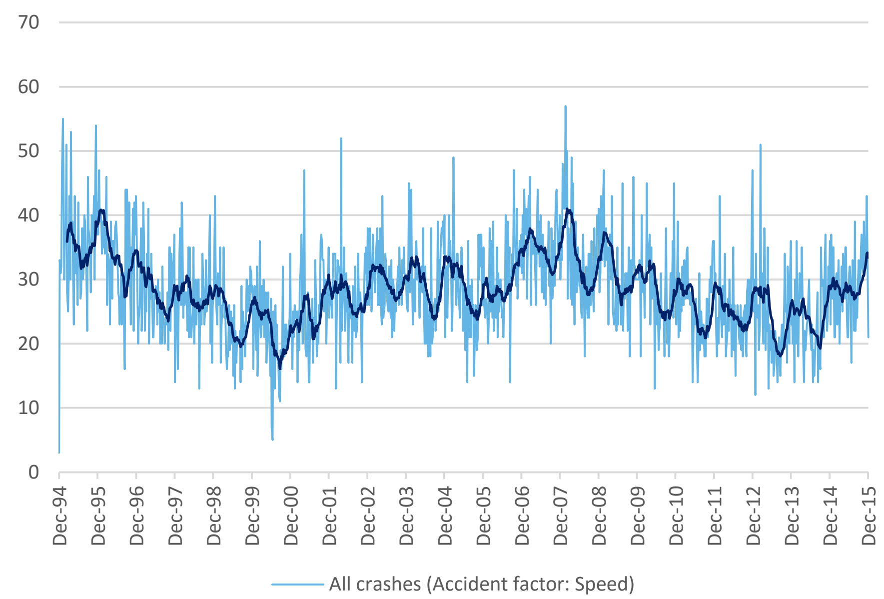
Chart A.12 Fatalities (LHS) and injuries (RHS) where speed was a contributing factor to the crash, by time of day



Source: CAS

The number of crashes where inappropriate speed was a contributing factor fluctuated somewhat over time (Chart A.13), with a peak in 2007 and 2008.

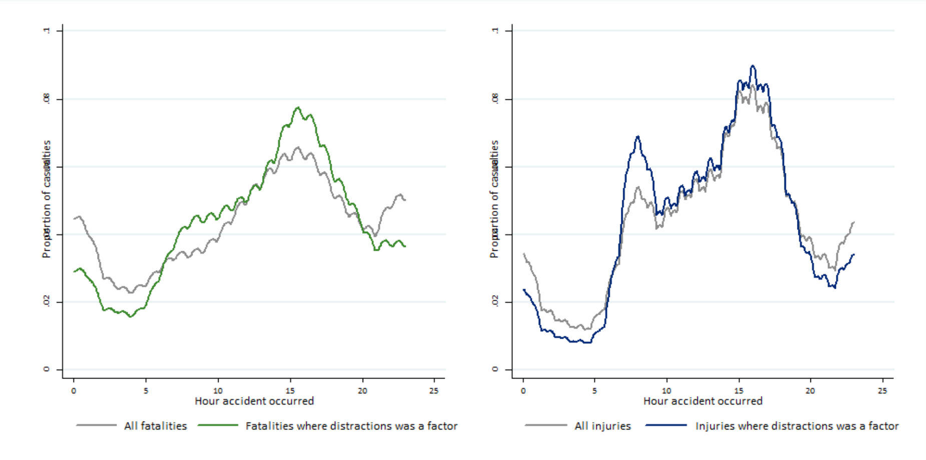
Chart A.13 All crashes where speed was a contributing factor, (weekly, with 12 week moving average, 1995-2015)



Source: CAS. Note: the dark blue line represents the twelve week moving average of the number of crashes – and is shown to smooth out weekly variability.

Distractions (due to both factors inside and outside of the vehicle) could lead to increased crash likelihood, particularly with the increasing use of mobile phones in vehicles, as discussed in Section 2.3. Chart A.14 shows that there is a spike in the number of injuries where distraction was a factor in both the morning and afternoon peak hours – this could relate to minor crashes where vehicles in congested roads fail to stop in time.

Chart A.14 Fatalities (LHS) and injuries (RHS) where distractions were a contributing factor to the crash, by time of day



Source: CAS

However, as the coding of these factors within the CAS are based on police reports – the ability to accurately identify the contributing factors, particularly for distraction, are based on the information provided by those involved in or who witnessed the crash. Thus, there may be degrees of under-reporting or mis-coding of factors, particularly if the crash is a fatal one. As such, the results of such analysis may be biased.

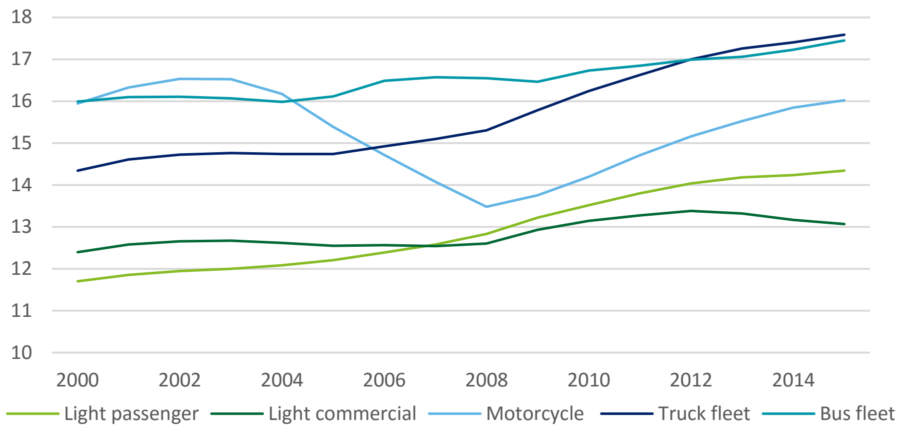
A.2. Independent variables

There are also a variety of independent variables, which are tested to determine if they have a relationship with changes in the road toll over time. These are described in this section.

Vehicle safety technology

The average age of the light passenger fleet in New Zealand has increased over time (Chart A.15), driven by increasing proportions of vehicles entering the fleet as used vehicles, and increasing average scrappage age. Used vehicles entering the fleet, on average, have fewer safety features than a new car entering in the same year. This is likely to have implications for the speed at which new vehicle safety technologies penetrate the fleet, and improve road safety, without government mandated rules.

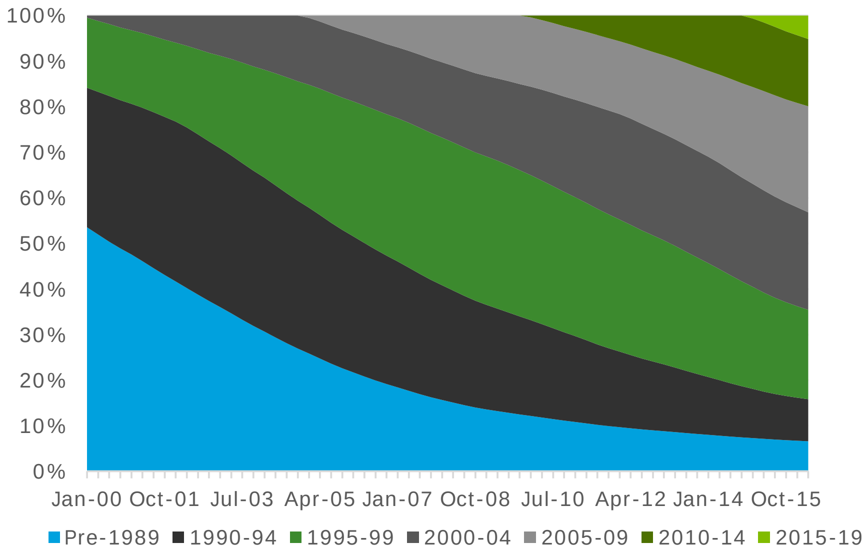
Chart A.15 Average age of vehicle fleet, by type (2000-2015)



Source: Ministry of Transport

The composition of the fleet by year of manufacture has changed over time. While the average vehicle age remaining fairly stable, there is a bulge of vehicles manufactured between 1995 and 1999 still in the fleet today (Chart A.16). This may have been the result of changes in second hand vehicle importation laws implemented in 2002 that required all imported passenger vehicles to comply with an overseas frontal impact standard, which effectively restricted used imports to those from 1996 and later.

Chart A.16 Composition of fleet by year of manufacture, over time (2000-2016)



Source: Ministry of Transport

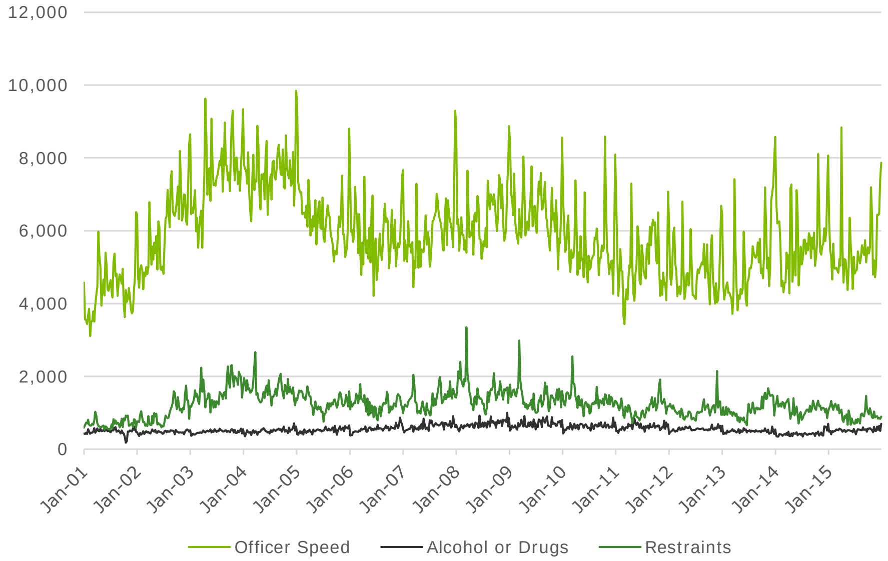
Changes to vehicle exhaust emission and vehicle emission testing rules in 2007 and 2012, may have also contributed to the changing distribution, encouraging uptake of more recent vehicles.

Police enforcement

Enforcement activity can create a deterrent effect that influences individual behaviour, but may decay over time, if that activity is not sustained.

Chart A.17 shows the number of on-the-spot issued speed, alcohol or drug related and restraint use (i.e. seatbelt) related infringements issued over time.

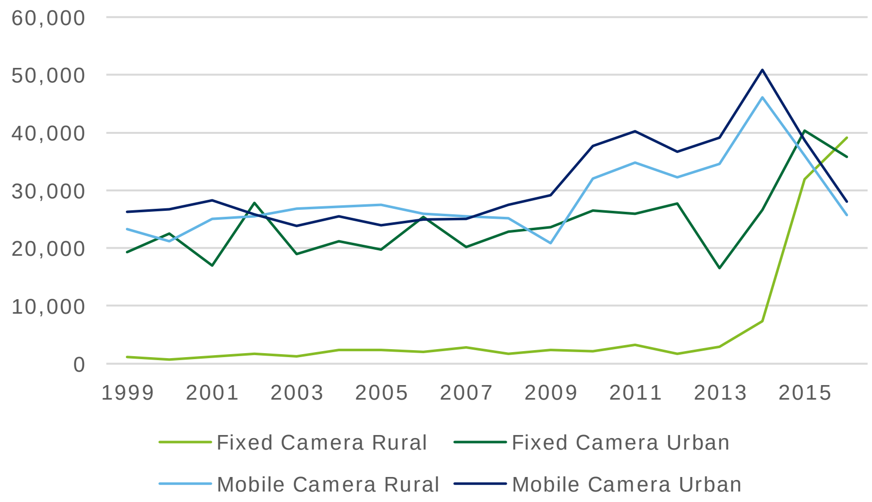
Chart A.17 Notices and infringements issued, by type (weekly, 1999-2015)



Source: New Zealand Police

Whilst there are fluctuations in the number of offences recorded, these figures depend, in part, on the level and targeting of enforcement activity and the rate of detection (not necessarily changes in the underlying rate of offending). For example, wet film fixed cameras do not operate continuously, as they are rotated across multiple sites. As such, speed camera operating hours fluctuate over time, whilst digital fixed cameras run continuously, barring a fault. This could be driving some of the rapid changes in the number of speeding detections as different camera technologies were introduced (Chart A.18).

Chart A.18 Speed camera operating hours, by type (1999-2015)



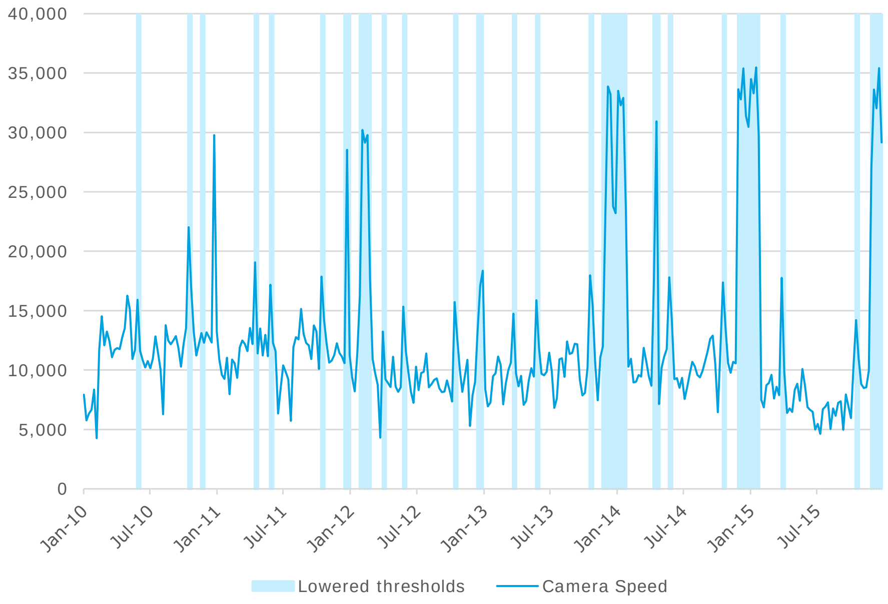
Source: New Zealand Police

There are also a number of temporary and permanent changes to policy that have occurred, which have served to tighten the tolerances around drink-driving and speeding, notably:

- lowering the legal alcohol breath and blood limit for drivers under the age of 20 to zero, from 7 August 2011;
- lowering the legal alcohol breath limit for drivers aged 20 and over to 250 micrograms per litre of breath (from 400 micrograms per litre of breath), from 1 December 2014; and over 'high-risk' and holiday periods (which may coincide with high VKT periods, and with a greater proportion of VKT on higher speed limit roads, thus increasing the injury severity in crashes), beginning in 2010, lowering the speed camera threshold from 10km/hr to 4km/hr.

These changes may impact on both the number and type of infringements issued, with the potential for step changes in detection over these time periods. This can be seen in the spikes in speed camera notices coinciding with periods where the enforcement threshold was lowered (Chart A.19).

Chart A.19 Speed camera infringements and lowered thresholds (monthly, 2010-2015)



Source: New Zealand Police

Public education campaigns

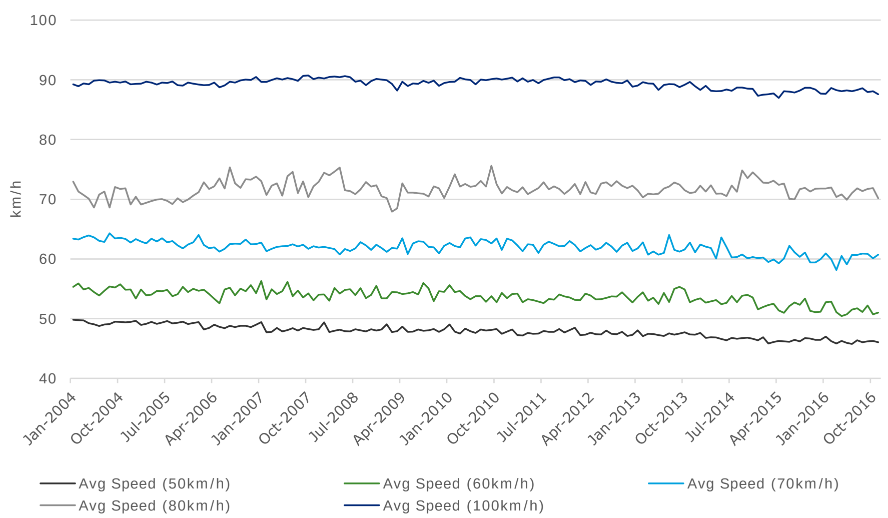
Advertising raises awareness amongst road users of the risks associated with certain behaviours, which can lead to behaviour change.

Themes targeted by road safety advertising in New Zealand include: alcohol and drugs, speeding, distractions, fatigue, restraint use, young drivers and motorcyclists. These are risk factors for crash likelihood and crash severity, and are incorporated into the modelling.

Observed speeds

Speed can influence crash likelihood and injury severity. Free speed data allows changes in road user behaviour to be observed over time. Average observed speeds have generally decreased slightly over time (Chart A.20), as have the proportion of individuals speeding.

Chart A.20 Average monthly observed speed, by speed zone (2004-2016)

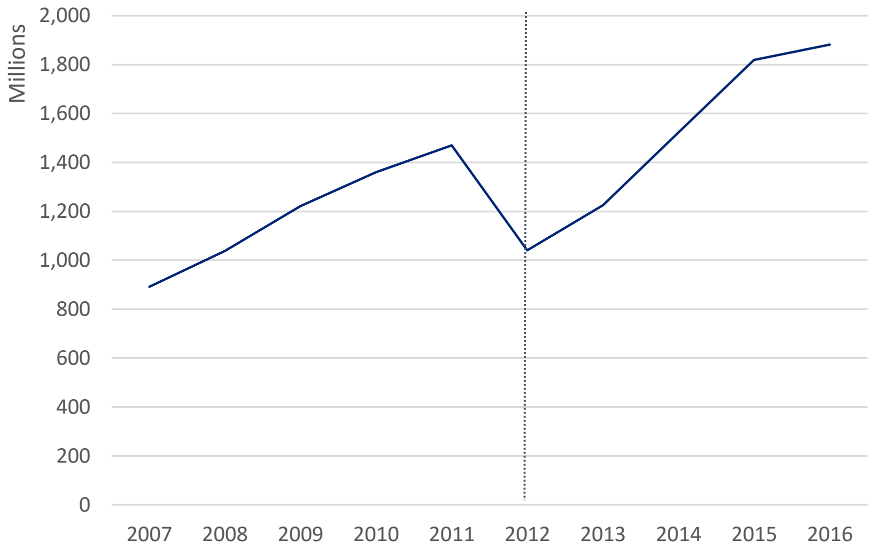


Source: New Zealand Police, mobile and fixed camera. Note: there is also data for the 30km/h, 40km/h and 90km/h speed limits, however, there are relatively few observations at these speeds and discontinuities in the series, and as such, are not presented here.

Road infrastructure

Road design can reduce crash likelihood (for example, through the use of roundabouts and rumble strips) and injury severity (for example, through the use of safety barriers). Infrastructure spending relating to, or targeted at, road safety is available back to 2012 – beyond that, only aggregate measures of spending are available (Chart A.21).

Chart A.21 Road safety infrastructure expenditure (nominal dollars)



Source: NZTA. Note: Infrastructure spending is categorised by when a location is completed, in order to take into consideration when improved roads come online into the road system.

However, the random component of crash location means that isolating the impact of infrastructure expenditure on an individual location can be difficult, particularly in a time-series econometric model. It is likely that

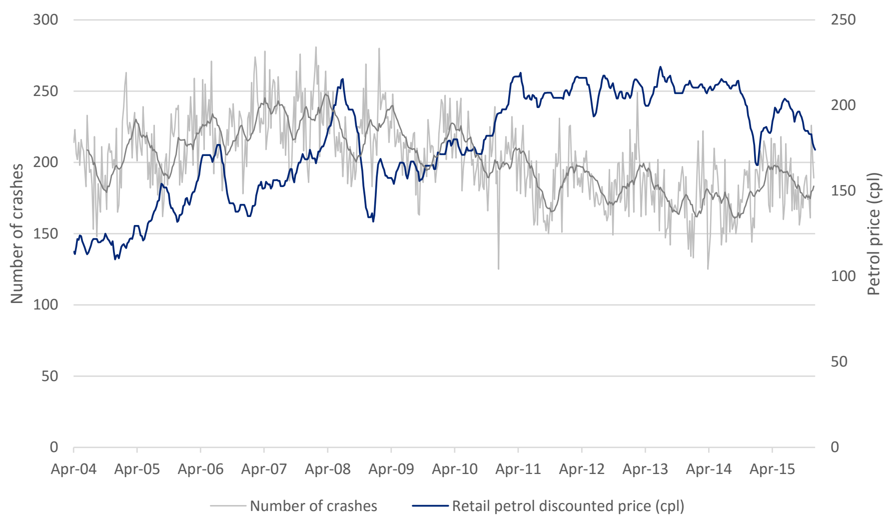
improvements in the overall level of road infrastructure will have an impact on road trauma in the long-term rather than being captured using our econometric approach.

Other data sources, such as KiwiRAP, allow for the analysis of road design and road safety features on crashes – however, this analysis is beyond the scope of this report. How this data could be used in future and ongoing research is described in Chapter 4.

Economic activity

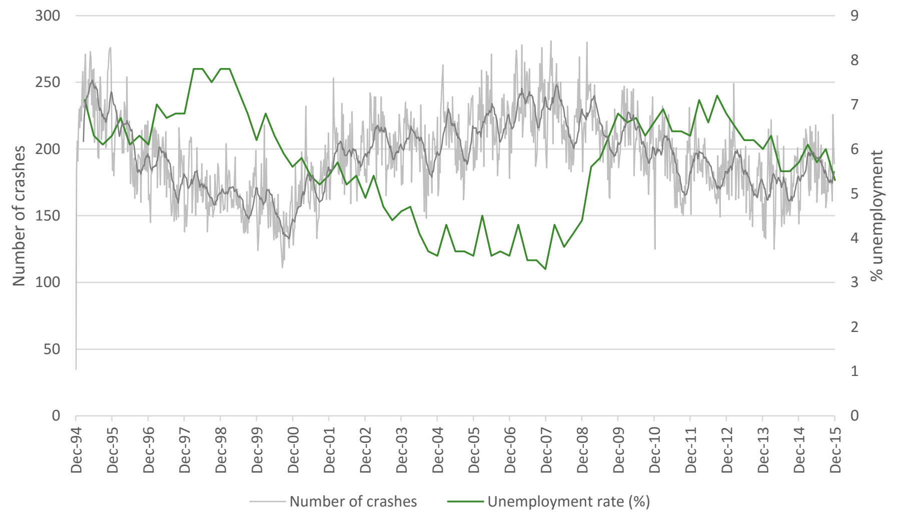
The level of economic activity can impact on number of vehicle kilometres travelled, and hence exposure to crash risk. There is some correlation between the number of crashes and fuel prices (Chart A.22), and the unemployment rate (Chart A.23), however changes in economic activity may only impact on travel volumes at the margin (for discretionary travel, reduced travel to workplaces and commercial travel). Decreases in the cost of alternate transport modes (such as lower airfares) may also influence the level of exposure to long distance driving (and potentially fatigue).

Chart A.22 Number of casualty crashes and fuel prices (weekly, 2004-2015)



Source: CAS; MBIE. Note: Dark grey line represents 12 week moving average of injuries.

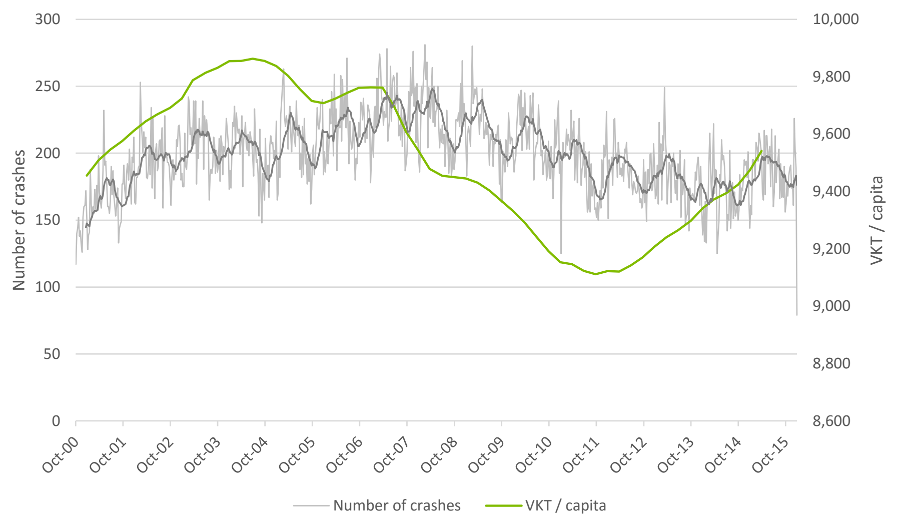
Chart A.23 Number of casualty crashes and unemployment rate (weekly, 1994-2015)



Source: Source: CAS; Statistics NZ. Note: Dark grey line represents 12 week moving average of crashes. Number of crashes are shown on the left Y-axis; Unemployment rate is shown on the right Y-axis.

The number of casualty crashes and vehicle kilometres travelled (VKT) per capita provide a measure of exposure to crash risk. Whilst there is a correlation between the two series, the modelling shows other factors are also important (Chart A.24).

Chart A.24 Number of casualty crashes and VKT/capita (2000-2015)



Source: CAS; MoT. Note: Dark grey line represents 12 week moving average of crashes. Number of crashes are shown on the left Y-axis; Unemployment rate is shown on the right Y-axis.

However, increases in vehicle kilometres travelled by heavy vehicles (such as trucks and buses, from an estimated 2.3 billion kilometres in 2001 to 3.0

billion kilometres in 2015) may have an impact on the severity of road trauma, particularly where those crashes involve smaller, lighter vehicles.

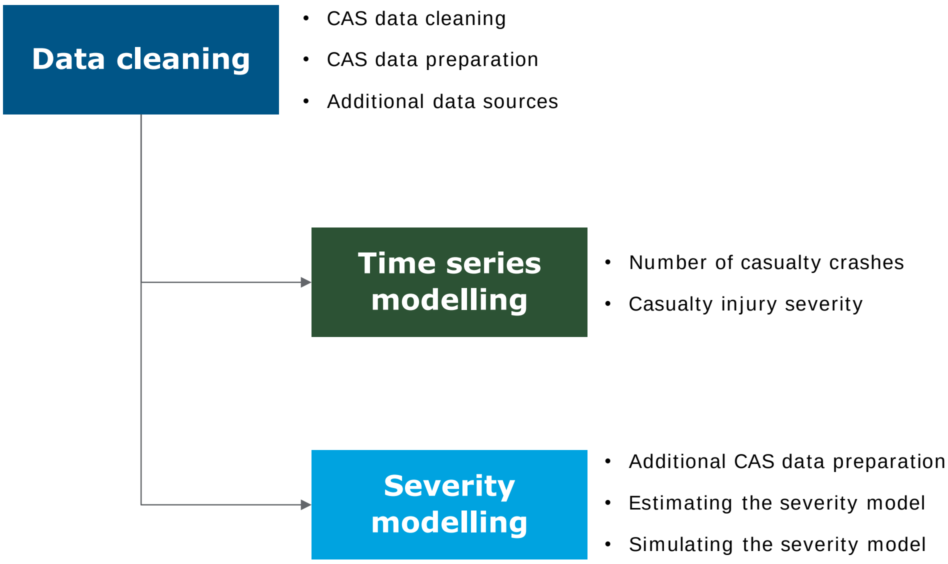
Seasonality

Time of year (including school holidays) and weather may also impact on exposure, crash risk and severity. However, the net impact of inclement weather on road trauma is unclear, as poor weather conditions may reduce the amount of exposure (as individuals delay discretionary travel) and crash risk (as individuals drive more carefully), or could increase crash risk (as the weather conditions are harder to drive in).

Appendix B : Econometric method

This technical appendix is designed to detail the road toll modelling exercise. Figure B.1 provides an overview of the process of data preparation and outlines key decisions made in the modelling process – which are then described in greater detail in the remainder of this appendix, whilst the following appendix (Appendix C) describes the detailed results of the modelling.

Figure B.1 : Modelling method overview



B.2. Data cleaning

B.2.1. CAS data

The CAS data was provided in four separate CSV files spanning 1995 to 2015. These files were read into Stata (the statistical software used in this analysis), and then appended together into one large data file.

An important step is ensuring that all key variables are of the same 'type' (i.e., string or numeric). Often, software will determine data type based on a 'first n observations' sample. This can sometimes mislabel string as numeric (and vice versa), leading to a large number of missing values.

As the unit of observation for time series modelling is the week, an important step is attributing dates of the year to a week in an equal manner (reflecting that there are not exactly four weeks to a month or 52 weeks to a year). For the purposes of the time series modelling a week must have seven days, commencing on the same day each week. Most software does not contain a built in function to map dates to these weeks as, for example, weeks constructed in this way can span over months or years.

The CAS data includes a number of variables that are not used in the time series modelling, as well as several casualty crashes that involved only minor injuries. These are removed from the data set prior to analysis.

The goal of the data cleaning stage is to produce a data set that contains all explanatory and dependent variables. In this step, indicators are created for whether a casualty crash involved one of the stratifications as detailed below (Table B.2).

Table B.1 : Stratified models, variable definition

Stratifying variable	Definition
Urban	Casualty crash occurred on a road with a speed limit between 5 and 70km/h.
Rural	Casualty crash occurred on a road with a speed limit between 80 and 100km/h (a small number of crashes have a recorded speed limit of 777km/h, these were removed only for the speed limit based stratifications).
Younger driver	Crash involved a driver between the ages of 16 and 24 (15 prior to 2011).
Older driver	Crash involved a driver greater than 75 years of age.
Motorcycle	Crash involved a motorcycle.
Pedestrian	Crash involved a pedestrian.
Cyclist	Crash involved a cyclist.
Impairment contributing	Alcohol or drugs were deemed a contributing factor in the crash.
Speed contributing	Speed was deemed a contributing factor in the crash.
Distraction contributing	Distraction was deemed a contributing factor in the crash.

The original CAS data is recorded at the individual level, requiring two steps to aggregate to the weekly level.

- First, indicators for the stratifying variables are aggregated to the crash level (as well as separate indicators for whether the casualty crash involved a serious injury or fatality). This produces a data set consisting of one row per crash.
- Then, these indicators are summed to the weekly level. This new data set consists of one row per week, with columns containing the number of casualty, serious injury, and fatality crashes, as well as the number of crashes involving at least one the of the stratifying indicators.

Finally, the first and last week observations are dropped (due to them containing an incomplete week).

B.2.2. Additional data

The CAS data did not contain any variables that could be used as explanatory variables in the modelling. That is, additional variables were required to explain the number of crashes in a given week.

Table B.2 : Additional data sources

Data	Description	Frequency
Recall	Advertising recall	Weekly

Fuel price	Average petrol price	Weekly
Speed observations	Mobile speed camera survey data	Monthly
Labour force status	Unemployment rate	Quarterly
Vehicle kilometres travelled	Vehicle kilometres travelled by the NZ fleet	Quarterly
Enforcement	Total traffic enforcements	Daily
Motorbikes	Motorcycle license fleet size	Monthly
Vehicle registrations		Monthly
Engine size	Light fleet engine size	Monthly
Advertising expenditure	Road safety advertising media spend	Monthly

Since modelling was undertaken on crash data aggregated to the weekly level, the majority of explanatory variables are interpolated to this level.

Interpolation for all monthly data sets (quarterly data sets which were assigned to the final month of the quarter) was performed in several steps:

1. Loop 'j' over the numbers 1 to 4 (corresponding to weeks in the month)
    a. Assign each monthly observation to week 'j' of the month
    b. Expand the data set to fill in missing weeks (with blanks in the place of each non-'j' week)
    c. Interpolate (linearly) the relevant set of explanatory variables over missing weeks
    d. Extrapolate (linearly) missing weeks at the tails of the data (for example, for 'j' = 1 the last 3 weeks will still be missing)
2. Merge the 4 new data sets (corresponding to weeks 1-4 of each month)
3. Average the interpolated variables across each commencing week
4. Data previously measured at the monthly level is now at the weekly frequency.

B.3. Model specification

There are several key characteristics of count data, such as the number of casualty crashes on NZ roads, which imply a linear model is not appropriate. Namely, count data is nonnegative and typically right skewed (observations are more likely to be further above the mean than below).

Count data is likely to be drawn from a Poisson distribution, which models the expected number of casualty crashes in a given week as:

$$E[crash_t] = e^{X_t \beta}$$

Where the X_t term refers to the set of explanatory variables.

For count data with a relatively large mean (typically above 10), and no zeros, the Poisson can be well approximated with a log-normal distribution. This amounts to log-transforming the equation above and estimating using least squares:

$$\ln crash_t = X_t \beta + \epsilon_t$$

This approximation is particularly useful when the error term exhibits persistence. This could occur, for example, when unobserved factors that affect the number of casualty crashes are correlated over time. Persistence in the error terms can be modelled using ARMA terms. However, there was little evidence of autocorrelation in the NZ data.

B.3.1. Variable selection

There was a relatively small set of explanatory variables available to be used in modelling the number of casualty crashes. In selecting which variables would be used in the final estimates, modelling tended to follow a general to specific approach.

The modelling approach involved starting with the full set of available explanatory variables, and reducing the set using tests of statistical significance. This method was generally fruitful due to the relatively large number of observations (600-700), and may not have been possible analysing the data at the monthly or quarterly level.

An important pitfall of this approach to variable selection was that it is more likely to find statistically significant explanatory variables by 'chance' (increasing the Type 1 error rate). Therefore, the final specification may be the result of data mining, and not hold true in practice.

This highlights the important role of placing theoretically sound priors on the specification and set of explanatory variables, and raises several questions that should be asked in determining the final set of results:

- Does the set of explanatory variables make sense, a priori?
- Do the estimates conform to theoretical priors (in terms of sign and significance)?
- Are the estimates equations robust to different specifications, both in including additional explanatory variables and using different lag specifications?

Finally, two additional sets of tests were performed after deciding on the final specification. An F-test was used as a measure of the collective importance of all excluded explanatory variables. A Hausman test was a final check for whether the remaining parameter estimates change significantly depending on the exclusion of other explanatory variables.

B.3.2. Casualty injury severity (time series)

The distribution of the weekly number of serious injury and fatal casualty crashes is such that a log-linear approximation is unlikely to be appropriate. These series were modelled using the Poisson distribution, which closely fits key characteristics of the data.

Instead of modelling the number of serious injury and fatal casualty crashes in a given week, the *rate* of severity/fatality per casualty crash was modelled. This was modelled in the Poisson framework using an exposure (or offset) term, consistent with the DRAG[19] approach. The expected severity rate in a given week is given as:

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[19] The DRAG approach is a component modelling approach (outlined by Bergel-Hayat and Zukowska, 2015), which decomposes fatalities into these four elements:
(1) fatalities per serious casualty;
(2) serious casualties per casualty (measure of severity);

$$E[severity_t] = crash_t e^{Z_t \Gamma}$$

Where Z_t is the relevant set of explanatory variables.

In this framework, it is less clear how persistence is accounted for. If it is expected that the form of persistence is not multiplicative, then log-lags of the dependent variable should be included in the set of explanatory variables. However, since, for example, the number of fatalities in a given week can be zero, it was not possible to directly take the log of the dependent variable.

In order to model persistence, an additional indicator variable was added, equal to 1 when the count is zero. This ensures that the log-dependent variable can be used, interacted with the indicator.

In additional to robustness tests for variable inclusion, there were additional tests that refer to assumptions made in the Poisson model. A key assumption is that the (conditional) mean is equal to the variance. If mis-specified, the standard errors of explanatory variables will be incorrectly estimated.

This variance assumption is often violated in practice, leading to either under of over dispersion, although over dispersion is more often observed empirically.

Several methods were utilised that accommodate for over-dispersion relative to the Poisson model. The most commonly employed is to model the variance as an additional term, the Negative Binomial model. Estimates from the Negative Binomial model are such that it is possible to statistically test for the presence of over-dispersion.

However, the common practice of comparing models to check for the consistency of implied results was adopted. These specifications included:

- Robust standard errors
- Estimating a variance scale factor in the Poisson model
- Estimating the full Negative Binomial model

The implications of each specification did not change substantially (that is, there was no practical difference between the estimates). As such, results from the Poisson model are presented below.

B.3.3. **Casualty injury severity (micro)**

Injury severity, as recorded in the CAS data, can take on several discrete categories:

- Fatal
- Serious
- Minor
- No injury (removed from analysis)

The 'distance' between each of these severity outcomes is not defined, so standard regression techniques are not applicable to data of this type.

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(3) casualties per kilometre (measure of crash likelihood); and
(4) kilometres travelled.
Such a structure means a model that includes all four components provides estimates for trends in fatalities, and a model that includes components (2), (3) and (4) provides estimates for serious casualty trends.

Instead, the outcomes are treated as categories, and the probability that, given a casualty crash has occurred, each injury severity level will be realised is modelled.

Following the method outlined in Weiss et al. (2014), a multinomial logit model was used.[20] This leads to the following expression for the expected probability of each severity level, given that a casualty crash has occurred:

$$p_{ij} = \frac{e^{X_i \beta_j}}{1 + \sum_{k=1}^{K-1} e^{X_i \beta_k}}$$

Where p_{ij} is the probability that individual *i* will be injured to a severity level of j, and $X_i\beta_j$ is the effect of explanatory variables. Standard errors are clustered at the crash level to account for correlation between individual severity levels in a given crash.

Coefficients from the estimated multinomial logit of injury severity cannot be interpreted in the same fashion as those from a linear model. Instead, the model was calculated and interpreted in terms of marginal effects. That is, effect of a marginal change (in the case of a continuous explanatory variables), or discrete step (in the case of categorical variables), on the probability of each injury severity level, given that a casualty crash has occurred.

Since the expected probability function is nonlinear, the marginal effect depends on the entire set of explanatory variables. Marginal effects were calculated as the average effect across the entire sample. This implies that a potentially large number of calculations have to be performed. Based on the CAS data sample (approximately 270,000 observations, standard errors of the marginal effects were not calculated for computational reasons.

[20] It was not feasible to relax the IIA assumption made by multinomial logit models due to computational complexities.

Appendix C : Detailed results

This appendix presents the analysis results for a number of different dependent variables, as well as additional interpretation and specification checks.

C.1. Time series modelling results

C.1.1. Casualty crashes

Coefficients from a (log-linear) model of the number of casualty crashes are displayed in Table A.4 below.

Table C.1 : Regression results, casualty crashes

Coefficient	Estimate	Standard error
Week 2	0.077	0.040
Week 3	0.125**	0.040
Week 4	0.148***	0.041
Week 5	0.171***	0.041
Week 6	0.194***	0.042
Week 7	0.286***	0.043
Week 8	0.267***	0.043
Week 9	0.263***	0.043
Week 10	0.227***	0.042
Week 11	0.231***	0.042
Week 12	0.258***	0.042
Week 13	0.181***	0.041
Week 14	0.200***	0.041
Week 15	0.170***	0.041
Week 16	0.140***	0.041
Week 17	0.151***	0.041
Week 18	0.196***	0.042
Week 19	0.217***	0.042
Week 20	0.189***	0.041
Week 21	0.239***	0.042
Week 22	0.220***	0.042
Week 23	0.152***	0.041
Week 24	0.176***	0.042
Week 25	0.165***	0.042
Week 26	0.148***	0.042

Coefficient	Estimate	Standard error
Week 27	0.106*	0.042
Week 28	0.120**	0.042
Week 29	0.118**	0.042
Week 30	0.086*	0.041
Week 31	0.071	0.041
Week 32	0.099*	0.041
Week 33	-0.003	0.042
Week 34	0.063	0.041
Week 35	0.024	0.041
Week 36	0.015	0.041
Week 37	-0.016	0.041
Week 38	-0.009	0.041
Week 39	-0.052	0.041
Week 40	-0.016	0.042
Week 41	0.030	0.042
Week 42	0.007	0.043
Week 43	0.010	0.041
Week 44	0.063	0.042
Week 45	0.059	0.043
Week 46	0.086*	0.044
Week 47	0.087*	0.044
Week 48	0.083	0.045
Week 49	0.074	0.045
Week 50	0.096*	0.044
Week 51	0.070	0.044
Week 52	0.098*	0.045
2005	-0.124***	0.035
2006	-0.263***	0.070
2007	-0.397***	0.107
2008	-0.577***	0.141
2009	-0.730***	0.164
2010	-0.802***	0.174
2011	-0.930***	0.179
2012	-0.987***	0.184
2013	-1.106***	0.193
2014	-1.301***	0.211
2015	-1.390***	0.233
Log VKT	2.522***	0.630
Log Motorbikes	1.585***	0.334
Log Enforcement	0.067*	0.030

Coefficient	Estimate	Standard error
Log Enforcement (t-1)	-0.099**	0.031
Proportion speeding (t-10)	-1.085**	0.408
Log crash (t-52)	-0.148***	0.041
Constant	-34.716***	7.722
R^2	66.1%	
N	614	

The estimated model can be used to unpack historic variations in the number of casualty crashes.

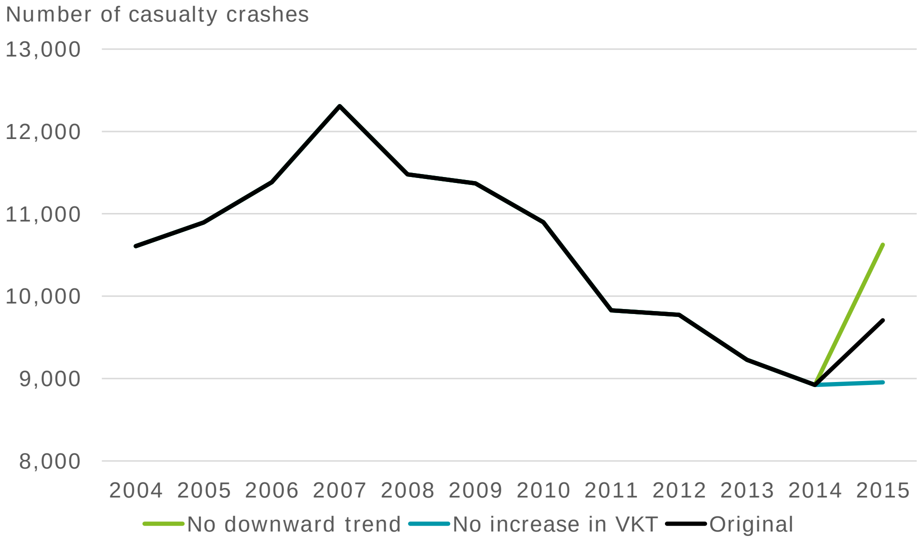
A simulation of the model was performed to determine important factors driving the uptick in casualty crashes in 2015, relative to historic trends. Two scenarios were run to illustrate the relative influence of a sharp increase in VKT, as well as the importance of a trending decline in the average number of casualty crashes.

Setting the 2015 level of VKT to 2014 levels, leaving all else constant, implies that the expected number of casualty crashes in 2015 would have been slightly below 2014 levels. This suggests that the increase in VKT was the largest contributor to the 2015 uptick.

The downward trend in the overall road toll is also an important (unexplained) factor that is driving a systematic decrease in the annual number of casualty crashes.

Setting the trend at 2014 levels, holding all else constant, implies a much larger uptick in the road toll.

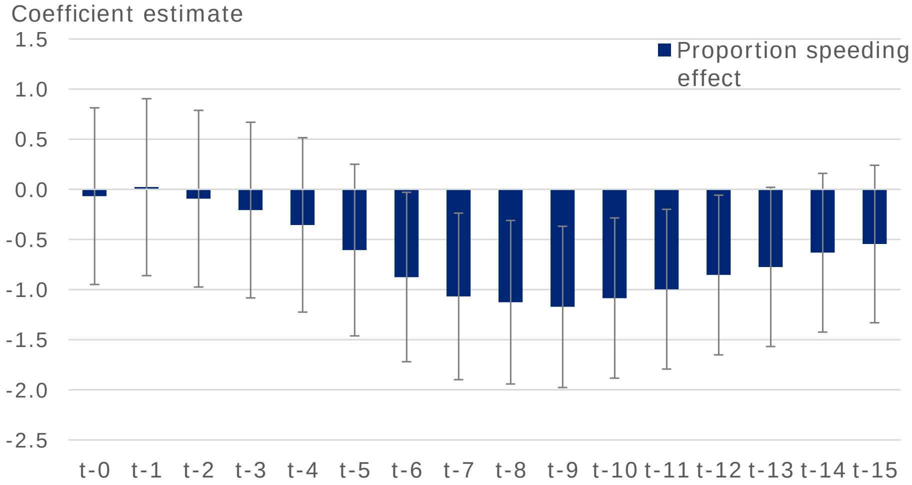
Chart C.1 : Casualty crash simulation



One specification issue that arose in the analysis of the number of casualty crashes each week was the stability of the proportion of speeding variables. In results presented above, the largest effect is selected. However, it was found that the estimated effect of the proportion of vehicles speeding did

not substantially change between the 7th and 12th lag (estimates presented in Chart C.2 below).

Chart C.2 : Casualty crash model, proportion speeding specification



Note: 95% confidence interval of estimate presented.

C.1.2. Severity rate modelling

Coefficient estimates of the exposure offset Poisson models of severity rate (relative to the total number of casualty crashes) are presented in Table C.2 below.

Table C.2 : Regression results, severity crashes

Coefficient	Serious injury rate	Fatality rate
2005	-0.011 (0.045)	
2006	0.043 (0.082)	
2007	-0.014 (0.120)	
2008	0.113 (0.160)	
2009	0.173 (0.184)	
2010	0.144 (0.195)	
2011	0.170 (0.208)	
2012	0.212 (0.214)	
2013	0.145 (0.222)	
2014	0.138 (0.237)	
2015	0.010 (0.255)	

Coefficient	Serious injury rate	Fatality rate
Week 52	0.090* (0.047)	0.352*** (0.100)
Log VKT	2.899*** (0.693)	1.942*** (0.736)
Log Motorbikes	-0.613* (0.371)	
Log Ad spend (t-4)	-0.0723** (0.0290)	
Proportion speeding (t-6)	-1.182* (0.644)	
Log fuel price		-0.422*** (0.0874)
Constant	-20.23*** (6.614)	-19.28*** (6.710)
N	618	608

The estimated coefficients from the injury severity models are interpreted in the same manner as the log-linear model of casualty crashes. However, the estimates are conditional on the number of casualty crashes (due to the offset term). That is, the estimated effects relate to the injury severity *rate*, rather than the count.

For example, an increase in VKT of 1% is associated with a 2.9% increase in the serious injury rate (the number of serious injury crashes per 100 casualty crashes).

This implies, together with the model for the number of casualty crashes, a compounding effect of explanatory variables (such as VKT). A 1% increase in VKT is associated with a 5.5% increase in the number of serious injury crashes (approximately 2.5%+2.9%), and a 4.4% increase in the number of fatal crashes (approximately 2.5%+1.9%)

C.1.3. **Stratified models**

Table C.3 on the following pages presents results for models estimated separately on stratifications of the number of casualty crashes in a given week. The definition of each stratification, as well as the model used, is available in Table C.2 above.

The purpose of the stratified models was to understand whether there were significant differences in the relationships between the explanatory variables and subsets of crash types. Broadly the results are consistent with the main model, with a few interesting findings:

- Increases in enforcement in the current period is associated with an increase in the number of urban crashes;
- Increases in unemployment are associated with a decrease in the number of young driver crashes;
- Increases in advertising spending are associated with a decrease in the number of older driver crashes; and
- Increases in unemployment is associated with a decrease in the number of pedestrian crashes five weeks later.

Table C.3 : Regression results, stratified models

Coefficient	Urban	Rural	Younger drivers	Older drivers	Motorcycles	Pedestrians	Cyclists	Impaired drivers	Speeding drivers	Distracted drivers
Week 2	0.112**	-0.00926	0.0632	0.0394	-0.0444	0.0911	0.172	0.0589	0.0620	-0.00902
Week 3	0.201***	0.00172	0.143**	0.0336	-0.0812	-0.0123	0.130	0.0559	0.102	0.0650
Week 4	0.226***	0.0660	0.172***	0.0848	-0.0152	0.143	0.455***	0.192***	0.102	0.0926
Week 5	0.260***	0.0456	0.183***	0.152	0.0857	0.363*	0.358***	0.168**	0.0847	0.186**
Week 6	0.327***	0.0773	0.212***	0.110	0.100	0.344*	0.585***	0.0827	0.132*	0.239***
Week 7	0.411***	0.115**	0.244***	0.0158	0.128	0.463**	0.539***	0.208***	0.226***	0.248***
Week 8	0.425***	0.0670	0.236***	0.0314	0.125	0.498***	0.678***	0.259***	0.117*	0.350***
Week 9	0.409***	0.0674	0.130**	0.0375	0.0934	0.544***	0.590***	0.199***	0.0956	0.347***
Week 10	0.360***	0.0660	0.189***	0.164	0.0581	0.516***	0.459***	0.115	0.0459	0.236***
Week 11	0.359***	0.0919	0.221***	0.244*	-0.0338	0.262	0.652***	0.160**	0.110	0.324***
Week 12	0.373***	0.0848	0.255***	0.315**	0.0301	0.507***	0.559***	0.172**	0.223***	0.360***
Week 13	0.319***	0.0231	0.230***	0.161	-0.0597	0.325	0.455***	0.152**	0.125*	0.219**
Week 14	0.342***	0.0275	0.222***	0.278**	0.00371	0.489**	0.243*	0.208***	0.146**	0.284***
Week 15	0.290***	0.0609	0.190***	0.305**	-0.0721	0.396**	0.211	0.0227	0.211***	0.205**
Week 16	0.266***	0.0107	0.186***	0.261*	-0.0534	0.264	0.0655	0.194***	0.150**	0.232***

Coefficient	Urban	Rural	Younger drivers	Older drivers	Motorcycles	Pedestrians	Cyclists	Impaired drivers	Speeding drivers	Distracted drivers
Week 17	0.321***	-0.0654	0.176***	0.0894	-0.180**	0.190	0.233*	0.0747	0.0787	0.131
Week 18	0.395***	-0.0579	0.226***	-0.107	-0.0829	0.426**	0.215	0.0491	0.0874	0.328***
Week 19	0.427***	-0.0776	0.227***	0.0301	-0.0431	0.550***	0.340**	0.119*	0.0932	0.309***
Week 20	0.379***	-0.0680	0.162***	0.175	-0.186**	0.373*	0.334**	0.139*	0.0702	0.228**
Week 21	0.410***	0.00556	0.274***	0.363***	-0.198**	0.466**	0.300**	0.175**	0.0426	0.341***
Week 22	0.368***	0.00673	0.217***	0.365**	-0.217**	0.146	0.317**	0.162**	0.0670	0.313***
Week 23	0.325***	-0.0306	0.164***	0.117	-0.294***	0.203	0.216	0.184**	0.0523	0.132
Week 24	0.356***	-0.0770	0.127**	-0.0453	-0.411***	0.233	0.182	0.182**	0.0150	0.124
Week 25	0.326***	-0.0361	0.109*	0.0193	-0.295***	0.278	0.237*	0.0984	-0.0495	0.0701
Week 26	0.290***	-0.00251	0.134**	0.0163	-0.427***	0.0851	0.197	0.135*	-0.000718	0.204**
Week 27	0.200***	0.0177	0.0686	0.115	-0.471***	-0.110	-0.0345	0.0384	-0.0372	0.0763
Week 28	0.237***	-0.00304	0.121**	0.185	-0.479***	0.185	-0.224*	0.159**	-0.0897	0.166*
Week 29	0.313***	-0.116**	0.107*	0.0102	-0.345***	0.0480	0.0556	0.150**	-0.154**	0.0937
Week 30	0.303***	-0.194***	0.0972*	0.00172	-0.366***	0.267	0.0457	0.112	-0.0880	0.106
Week 31	0.264***	-0.173***	0.00809	0.0157	-0.284***	0.0365	0.0947	0.143**	-0.130*	0.102
Week 32	0.324***	-0.216***	0.127**	-0.0709	-0.328***	0.222	0.101	0.0798	0.0949	0.0267
Week 33	0.222***	-0.256***	0.00129	-0.0744	-0.407***	0.0863	-0.0540	0.0963	-0.219***	0.195**

Coefficient	Urban	Rural	Younger drivers	Older drivers	Motorcycles	Pedestrians	Cyclists	Impaired drivers	Speeding drivers	Distracted drivers
Week 34	0.258***	-0.134**	0.104*	0.0624	-0.298***	-0.0128	0.141	0.146**	0.0530	0.132
Week 35	0.249***	-0.278***	0.00840	0.252*	-0.238***	0.237	0.154	0.104	-0.0205	0.0942
Week 36	0.238***	-0.283***	0.0312	-0.00825	-0.301***	-0.0488	-0.0554	0.101	-0.143*	0.143
Week 37	0.201***	-0.324***	-0.0499	0.0727	-0.350***	0.119	0.115	0.0920	-0.193***	0.0706
Week 38	0.132***	-0.159***	0.00358	-0.0332	-0.284***	0.0467	-0.0493	0.0298	-0.0868	-0.0159
Week 39	0.0862*	-0.187***	-0.0473	-0.0308	-0.345***	-0.0896	0.0818	0.0688	-0.0687	-0.108
Week 40	0.0957**	-0.116*	-0.00717	-0.0431	-0.353***	-0.260	-0.0226	0.200***	-0.0864	-0.0948
Week 41	0.211***	-0.183***	0.0829	-0.0992	-0.162*	-0.0499	0.200	0.263***	-0.0526	-0.0117
Week 42	0.142***	-0.147**	-0.0548	0.0249	-0.202**	0.0177	0.144	0.184***	0.0212	0.145
Week 43	0.156***	-0.164***	-0.00773	-0.221	-0.0587	-0.112	0.218*	0.143**	0.0375	0.0843
Week 44	0.219***	-0.154**	-0.0158	-0.0189	-0.0604	0.169	0.368***	0.139*	-0.128*	0.144
Week 45	0.180***	-0.133**	-0.0129	0.165	-0.119	0.171	0.295**	0.206***	-0.0424	0.0582
Week 46	0.199***	-0.0813	0.0316	0.220	-0.0821	0.176	0.276**	0.208***	0.0656	0.151
Week 47	0.181***	-0.0346	0.0284	0.0833	-0.0780	0.0295	0.225*	0.200***	0.0327	0.0752
Week 48	0.188***	-0.0491	0.0310	0.00656	-0.189**	-0.0509	0.213	0.209***	0.0696	0.0238
Week 49	0.166***	-0.0315	0.0920	-0.116	-0.108	0.171	0.0595	0.212***	-0.00316	0.0699
Week 50	0.219***	-0.0476	0.0227	0.177	-0.182**	0.0214	0.0104	0.277***	0.138**	0.0536

Coefficient	Urban	Rural	Younger drivers	Older drivers	Motorcycles	Pedestrians	Cyclists	Impaired drivers	Speeding drivers	Distracted drivers
Week 51	-0.00374	0.145**	0.0552	0.202	-0.0183	-0.00503	-0.373***	0.197***	0.0535	0.00448
Week 52	-0.0290	0.307***	0.253***	0.183	-0.106	-0.275	-0.187	0.439***	0.366***	0.0636
2002	0.0335		-0.00910	-0.275**	0.0927*	0.201		0.107***	-0.135***	
2003	-0.0693		-0.107	-0.433***	0.101	0.202		0.0715*	-0.213***	
2004	-0.278***		-0.345***	-0.500**	-0.0193	-0.156		0.0618	-0.390***	
2005	-0.411***	-0.104**	-0.510***	-0.587**	0.112	-0.360	0.0202	0.149***	-0.490***	-0.233***
2006	-0.547***	-0.211**	-0.672***	-0.437*	0.0736	-0.490	0.0271	0.290***	-0.440***	-0.484***
2007	-0.692***	-0.324**	-0.865***	-0.453*	0.215	-0.633	0.0819	0.350***	-0.349***	-0.640***
2008	-0.860***	-0.485**	-1.093***	-0.393*	0.131	-0.895	-0.0164	0.334***	-0.320***	-0.884***
2009	-1.029***	-0.585**	-1.232***	-0.273	0.000253	-0.932	0.00204	0.287***	-0.385***	-1.077***
2010	-1.110***	-0.641**	-1.332***	-0.366	-0.0916	-0.936	-0.0573	0.190***	-0.489***	-1.134***
2011	-1.211***	-0.780***	-1.509***	-0.382*	-0.201	-1.018	-0.196	0.107**	-0.518***	-1.378***
2012	-1.241***	-0.869***	-1.618***	-0.228	-0.223	-1.115	-0.187	0.0924**	-0.541***	-1.518***
2013	-1.350***	-1.019***	-1.815***	-0.483**	-0.240	-1.055	-0.188	-0.0158	-0.694***	-1.664***
2014	-1.551***	-1.247***	-2.044***	-0.709**	-0.262	-1.305	-0.302*	-0.0880**	-0.846***	-1.753***
2015	-1.657***	-1.332***	-2.160***	-0.757**	-0.260	-1.683	-0.225	-0.0269	-0.818***	-1.815***
Log VKT	2.908***	3.438***	3.970***	5.972***					5.570***	

Coefficient	Urban	Rural	Younger drivers	Older drivers	Motorcycles	Pedestrians	Cyclists	Impaired drivers	Speeding drivers	Distracted drivers
Log Motorbikes	1.727***	1.094**	2.055***		1.257*	3.902**				2.425***
Log Enforcement	-0.125***		0.0929**		0.264***	0.308**	0.296***	0.130***		
Log Enforcement (t-1)	-0.125***		-0.0239		-0.323***	-0.434***	-0.251**			
Log Enforcement (t-2)			-0.0586							
Log Enforcement (t-3)			-0.106**							
Proportion speeding (t-10)										
Log *depvar* (t-1)				-0.124***			0.092**			
Log *depvar* (t-52)	-0.074***	-0.191***	-0.130***	-0.074**			-0.120***	-0.067**	-0.056*	-0.073*
Depvar dummy (t-1)				-0.039						
Depvar dummy (t-52)				0.090						
Unemployment rate			-0.488**							
Unemployment rate (t-5)						-17.33***				

Coefficient	Urban	Rural	Younger drivers	Older drivers	Motorcycles	Pedestrians	Cyclists	Impaired drivers	Speeding drivers	Distracted drivers
Proportion speeding (t-4)										-2.154**
Proportion speeding (t-7)		-2.597***								
Log ad spend				-0.035**						
Log fuel price							0.591**			
Constant	-40.93***	-38.19***	-54.05***	-51.97***	-10.93	-41.47**	-0.874	1.955***	-47.41***	-23.79***
R^2	58.2%	60.7%					39.2%			
N	771	617	771	754	778	778	608	779	771	620

C.2. Microeconometric severity modelling results

Coefficient estimates from the multinomial logit model of casualty crash injury severity are presented in Table C.4 below. Standard errors are clustered at the accident level.

Table C.4 : Severity model coefficient estimates

Variable	Coefficient estimate (Serious)	P-value (Serious)	Coefficient estimate (Fatal)	P-value (Fatal)
Age	0.008***	0.0000	-0.020***	0.0000
Age squared	0.000	0.0714	0.001***	0.0000
Zero years old	0.514	0.0635	2.090***	0.0000
Male	0.029*	0.0257	0.121***	0.0000
Road type (relative to minor urban road)				
Major urban road	-0.046*	0.0104	0.050	0.3536
Open other road	0.214***	0.0000	0.511***	0.0000
Open road state highway	0.293***	0.0000	0.859***	0.0000
Urban state highway	0.060*	0.0226	0.455***	0.0000
Motorway	-0.389***	0.0000	-0.235*	0.0380
Weather (relative to fine) and lighting (relative to bright sun)				
Mist	-0.152**	0.0022	-0.043	0.6603
Light rain	-0.112***	0.0000	-0.171***	0.0000
Heavy rain	-0.079*	0.0101	-0.195**	0.0036
Snow	-0.064	0.5919	-0.324	0.2445
Frost	-0.110*	0.0480	-0.355*	0.0145
Strong wind	-0.025	0.5890	0.270**	0.0017
Dark	0.043	0.1132	0.219***	0.0005
Overcast	-0.052***	0.0010	-0.074*	0.0493
Twilight	0.014	0.6658	0.056	0.4722
Speed (relative to ≥ 50km/h and ≤ 70km/h)				
Speed zone < 50km/h	-0.345***	0.0000	-0.955***	0.0000
Speed zone > 70km/h and < 100km/h	-0.264***	0.0000	-1.037***	0.0000
Speed zone ≥ 100km/h	-0.169***	0.0000	-0.426***	0.0000
Interaction terms				
Two parties in a high speed zone	0.499***	0.0000	1.246***	0.0000
Three or more parties in a high speed zone	0.575***	0.0000	1.276***	0.0000
Two parties in a medium speed zone	0.378***	0.0000	1.346***	0.0000
Three or more parties in a medium speed zone	0.401***	0.0002	1.414***	0.0000
Individual role (relative to driver)				
Passenger	-0.073	0.5121	0.202	0.3791

Variable	Coefficient estimate (Serious)	P-value (Serious)	Coefficient estimate (Fatal)	P-value (Fatal)
Neither driver not passenger	-0.600*	0.0357	-0.747	0.0689
Crash involved a driver who was				
Male	0.118***	0.0000	0.416***	0.0000
Young (< 25 years old)	-0.022	0.3164	-0.027	0.6218
Young (< 25 years old) and Male	0.032	0.1729	-0.092	0.1141
Vehicle type (relative to car)				
Van or utility	0.048*	0.0330	-0.131**	0.0093
Truck or SUV	-0.046	0.0771	-0.094	0.0897
Bus	-0.277	0.0943	-1.443***	0.0001
Motorcycle	1.416***	0.0000	1.393***	0.0000
Pedestrian	2.110***	0.0000	2.989***	0.0000
Cyclist	1.738***	0.0000	2.206***	0.0000
Other	0.685***	0.0000	1.049***	0.0002
Licence status (relative to full licence)				
Restricted	-0.010	0.5724	-0.037	0.3888
Learner	0.034	0.1025	-0.041	0.3986
Disqualified or Forbidden	0.156***	0.0000	0.177**	0.0092
Expired	0.276***	0.0000	0.213	0.0736
Never licensed	0.129***	0.0000	0.283***	0.0000
Other (not driver)	0.705**	0.0014	1.155**	0.0011
Overseas driver	-0.131***	0.0000	-0.267***	0.0000
Wrong license class	0.242***	0.0009	0.582***	0.0000
Number of parties (relative to single vehicle crash)				
Two vehicles	-0.363***	0.0000	-1.138***	0.0000
Three or more vehicles	-0.308***	0.0000	-0.922***	0.0000
Crash factors (relative to other crash factors)				
Speed	0.227***	0.0000	0.532***	0.0000
Distractions	-0.023	0.4007	-0.029	0.6532
Failure to give way	-0.123***	0.0000	-0.538***	0.0000
Alcohol or drugs	0.461***	0.0000	0.756***	0.0000
Individual factors (relative to other individual factors)				
Speed	0.024	0.4019	0.419***	0.0000
Distractions	-0.020	0.5857	0.134	0.1183
Failure to give way	0.060*	0.0306	0.365***	0.0000
Alcohol or drugs	0.168***	0.0000	0.191***	0.0005
Vehicle age				
Vehicle age	0.014***	0.0000	0.020***	0.0000
Vehicle zero years	-0.027	0.8127	0.058	0.8040

Variable	Coefficient estimate (Serious)	P-value (Serious)	Coefficient estimate (Fatal)	P-value (Fatal)
Vehicle movement (relative to overtaking and lane change / pulling out or changing lane to the right)				
Head on	0.600***	0.0000	0.598***	0.0000
Lost control or off road (straight roads)	-0.012	0.7876	-0.731***	0.0000
Cornering	-0.108*	0.0132	-0.939***	0.0000
Collision with obstruction	-0.113*	0.0132	-1.006***	0.0000
Rear end	-0.915***	0.0000	-1.701***	0.0000
Turning versus same direction	-0.387***	0.0000	-1.081***	0.0000
Crossing (no turns)	-0.035	0.4347	-0.187	0.0675
Crossing (vehicle turning)	-0.115*	0.0128	-0.670***	0.0000
Merging	-0.341***	0.0000	-1.122***	0.0000
Right turn against	-0.010	0.8360	-0.734***	0.0000
Manoeuvring	-0.215***	0.0000	-0.872***	0.0000
Pedestrians crossing road	-0.093	0.1626	-0.309*	0.0225
Pedestrians other	-0.069	0.3863	0.286*	0.0460
Miscellaneous	0.776***	0.0000	1.464***	0.0000
Type B	-0.004	0.8127	-0.028	0.4403
Type C	-0.041	0.0649	-0.091	0.0507
Type D	-0.200***	0.0000	-0.599***	0.0000
Type E	0.007	0.8347	-0.151	0.0531
Type F	-0.144***	0.0000	-0.380***	0.0000
Type G	-0.622***	0.0000	-1.643***	0.0000
Type O	-0.166***	0.0003	-0.373***	0.0000
Year (relative to 1995)				
1996	0.100**	0.0045	0.005	0.9495
1997	0.068	0.0587	0.152*	0.0453
1998	0.033	0.3651	0.112	0.1516
1999	0.114**	0.0019	0.155*	0.0460
2000	0.115**	0.0024	0.194*	0.0167
2001	0.093*	0.0107	0.050	0.5291
2002	0.035	0.3308	-0.118	0.1387
2003	0.012	0.7248	-0.011	0.8826
2004	0.018	0.6204	-0.063	0.4322
2005	-0.030	0.3961	-0.128	0.1277
2006	-0.037	0.2986	-0.238**	0.0032
2007	-0.109**	0.0023	-0.230**	0.0035
2008	-0.118***	0.0009	-0.308***	0.0002
2009	-0.115**	0.0017	-0.221**	0.0066
2010	-0.162***	0.0000	-0.232**	0.0043

Variable	Coefficient estimate (Serious)	P-value (Serious)	Coefficient estimate (Fatal)	P-value (Fatal)
2011	-0.148***	0.0001	-0.408***	0.0000
2012	-0.130***	0.0005	-0.352***	0.0001
2013	-0.146***	0.0001	-0.483***	0.0000
2014	-0.056	0.1433	-0.332***	0.0002
2015	-0.088*	0.0194	-0.287***	0.0008
Local Government Region (relative to Auckland)				
Northland	0.080*	0.0102	0.024	0.6999
Waikato	0.092***	0.0000	0.188***	0.0001
Bay of Plenty	0.153***	0.0000	0.165**	0.0053
Gisborne	0.056	0.3093	-0.075	0.5535
Hawkes Bay	0.171***	0.0000	0.099	0.1566
Taranaki	0.060	0.0994	-0.202*	0.0130
Manawatu / Wanganui	0.153***	0.0000	0.073	0.1992
Wellington	0.063**	0.0080	-0.319***	0.0000
Nelson / Marlborough	0.134***	0.0001	-0.229**	0.0048
West Coast	0.265***	0.0000	0.133	0.2094
Canterbury	0.243***	0.0000	0.088	0.0841
Otago	0.338***	0.0000	-0.291***	0.0000
Southland	0.298***	0.0000	-0.212*	0.0107
Hour of day (relative to 23:00)				
00:00	0.023	0.6675	-0.031	0.7528
01:00	0.080	0.1649	0.054	0.6077
02:00	-0.011	0.8578	0.165	0.1264
03:00	-0.045	0.4840	0.009	0.9353
04:00	0.003	0.9551	0.103	0.3734
05:00	0.004	0.9385	0.119	0.2641
06:00	-0.096	0.0799	-0.224*	0.0492
07:00	-0.283***	0.0000	-0.509***	0.0000
08:00	-0.228***	0.0001	-0.479***	0.0000
09:00	-0.183**	0.0010	-0.507***	0.0000
10:00	-0.201***	0.0003	-0.482***	0.0000
11:00	-0.174**	0.0013	-0.364**	0.0011
12:00	-0.171**	0.0016	-0.358**	0.0012
13:00	-0.220***	0.0000	-0.508***	0.0000
14:00	-0.170**	0.0012	-0.564***	0.0000
15:00	-0.165**	0.0015	-0.448***	0.0000
16:00	-0.167***	0.0008	-0.478***	0.0000
17:00	-0.121*	0.0132	-0.479***	0.0000
18:00	-0.109*	0.0281	-0.407***	0.0000

Variable	Coefficient estimate (Serious)	P-value (Serious)	Coefficient estimate (Fatal)	P-value (Fatal)
19:00	-0.097	0.0525	-0.236*	0.0164
20:00	-0.092	0.0690	-0.308**	0.0019
21:00	-0.048	0.3475	-0.297**	0.0033
22:00	-0.075	0.1540	-0.111	0.2641
Day of week (relative to Monday)				
Tuesday	0.043	0.0657	0.033	0.5226
Wednesday	0.021	0.3704	0.090	0.0751
Thursday	0.019	0.4004	0.104*	0.0410
Friday	-0.010	0.6524	0.065	0.1749
Saturday	0.021	0.3303	0.040	0.3884
Sunday	0.026	0.2248	0.018	0.6787
Constant	-1.998***	0.0000	-3.170***	0.0000

Source: Deloitte Access Economics (2016)

As mentioned above, the estimates of a multinomial logit model are not, in themselves, meaningful. Instead, marginal effects are calculated for each of the explanatory variables (presented in Table C.5 below).

Table C.5 Severity model marginal effects

Variable	P(injury=minor)	P(injury=severe)	P(injury=fatal)
Age	-0.002	0.001	0.000
Zero years old	-0.148	0.034	0.114
Male	-0.006	0.003	0.003
Road type (relative to minor urban road)			
Major urban road	0.005	-0.006	0.001
Open other road	-0.036	0.026	0.010
Open road state highway	-0.054	0.034	0.021
Urban state highway	-0.015	0.005	0.010
Motorway	0.046	-0.043	-0.002
Weather (relative to fine) and lighting (relative to bright sun)			
Mist	0.019	-0.019	0.000
Light rain	0.017	-0.013	-0.004
Heavy rain	0.013	-0.009	-0.004
Snow	0.014	-0.006	-0.007
Frost	0.020	-0.012	-0.008
Strong wind	-0.003	-0.006	0.008
Dark	-0.010	0.004	0.006
Overcast	0.008	-0.006	-0.001

Variable	P(injury=minor)	P(injury=severe)	P(injury=fatal)
Twilight	-0.003	0.001	0.001
Speed (relative to ≥ 50km/h and ≤ 70km/h)			
Speed zone < 50km/h	0.060	-0.040	-0.021
Speed zone > 70km/h and < 100km/h	0.003	-0.001	-0.002
Speed zone ≥ 100km/h	-0.027	0.020	0.007
Individual role (relative to driver)			
Passenger	0.005	-0.012	0.007
Neither driver not passenger	0.080	-0.067	-0.013
Crash involved a driver who was			
Male	-0.022	0.012	0.009
Young (< 25 years old)	0.003	-0.003	-0.001
Young (< 25 years old) and Male	-0.002	0.005	-0.003
Vehicle type (relative to car)			
Van or utility	-0.003	0.006	-0.003
Truck or SUV	0.006	-0.004	-0.002
Bus	0.042	-0.023	-0.018
Motorcycle	-0.233	0.205	0.028
Pedestrian	-0.401	0.289	0.112
Cyclist	-0.311	0.247	0.065
Other	-0.107	0.080	0.027
Licence status (relative to full licence)			
Restricted	0.002	-0.001	-0.001
Learner	-0.004	0.005	-0.001
Disqualified or Forbidden	-0.024	0.020	0.004
Expired	-0.041	0.038	0.004
Never licensed	-0.022	0.015	0.007
Other (not driver)	-0.130	0.094	0.036
Overseas driver	0.021	-0.015	-0.006
Wrong license class	-0.045	0.028	0.017
Number of parties (relative to single vehicle crash)			
Two vehicles	0.022	-0.014	-0.008
Three or more vehicles	0.006	-0.003	-0.003
Crash factors (relative to other crash factors)			
Speed	-0.040	0.027	0.014
Distractions	0.003	-0.003	-0.001

Variable	P(injury=minor)	P(injury=severe)	P(injury=fatal)
Failure to give way	0.024	-0.013	-0.012
Alcohol or drugs	-0.078	0.059	0.019
Individual factors (relative to other individual factors)			
Speed	-0.012	-0.001	0.013
Distractions	-0.000	-0.004	0.004
Failure to give way	-0.015	0.005	0.011
Alcohol or drugs	-0.025	0.022	0.004
Vehicle age			
Vehicle age	-0.002	0.002	0.000
Vehicle zero years	0.002	-0.004	0.002
Vehicle movement (relative to overtaking and lane change / pulling out or changing lane to the right)			
Head on	-0.106	0.086	0.019
Lost control or off road (straight roads)	0.018	0.005	-0.022
Cornering	0.033	-0.007	-0.026
Collision with obstruction	0.035	-0.008	-0.027
Rear end	0.123	-0.088	-0.035
Turning versus same direction	0.068	-0.040	-0.027
Crossing (no turns)	0.010	-0.003	-0.007
Crossing (vehicle turning)	0.030	-0.010	-0.020
Merging	0.063	-0.035	-0.028
Right turn against	0.018	0.005	-0.022
Manoeuvring	0.045	-0.021	-0.024
Pedestrians crossing road	0.020	-0.009	-0.010
Pedestrians other	-0.001	-0.013	0.014
Miscellaneous	-0.172	0.094	0.078
Type B	0.001	-0.000	-0.001
Type C	0.007	-0.005	-0.002
Type D	0.035	-0.022	-0.013
Type E	0.002	0.002	-0.004
Type F	0.025	-0.016	-0.009
Type G	0.089	-0.064	-0.025
Type O	0.027	-0.019	-0.008
Year (relative to 1995)			
1996	-0.013	0.014	-0.001
1997	-0.012	0.008	0.004
1998	-0.007	0.003	0.003

Variable	P(injury=minor)	P(injury=severe)	P(injury=fatal)
1999	-0.018	0.014	0.004
2000	-0.019	0.014	0.005
2001	-0.013	0.012	0.001
2002	-0.002	0.006	-0.004
2003	-0.001	0.002	-0.000
2004	-0.001	0.003	-0.002
2005	0.006	-0.003	-0.003
2006	0.009	-0.003	-0.006
2007	0.018	-0.013	-0.005
2008	0.020	-0.013	-0.007
2009	0.018	-0.013	-0.005
2010	0.024	-0.019	-0.005
2011	0.026	-0.016	-0.009
2012	0.022	-0.014	-0.008
2013	0.027	-0.016	-0.011
2014	0.013	-0.005	-0.008
2015	0.016	-0.009	-0.007
Local Government Region (relative to Auckland)			
Northland	-0.010	0.010	0.000
Waikato	-0.015	0.010	0.005
Bay of Plenty	-0.022	0.018	0.004
Gisborne	-0.005	0.008	-0.002
Hawkes Bay	-0.023	0.021	0.001
Taranaki	-0.004	0.009	-0.006
Manawatu / Wanganui	-0.020	0.019	0.001
Wellington	-0.002	0.010	-0.008
Nelson / Marlborough	-0.012	0.019	-0.007
West Coast	-0.036	0.035	0.002
Canterbury	-0.032	0.032	0.000
Otago	-0.039	0.049	-0.009
Southland	-0.035	0.042	-0.007

Source: Deloitte Access Economics (2016)

The regional results suggest that there is a greater likelihood of a severe injury occurring (relative to a minor injury) if the crash occurs in a region other than Auckland – with the greatest differences in the Otago (4.9 percentage points), Southland (4.2 percentage points) and West Coast (3.5 percentage points) regions.

This could be the result of systematic differences across these regions in road infrastructure, vehicles in these regions, or road user (characteristics or behaviours) that are not explicitly captured in the variables that have been included in the modelling – however there is incomplete information

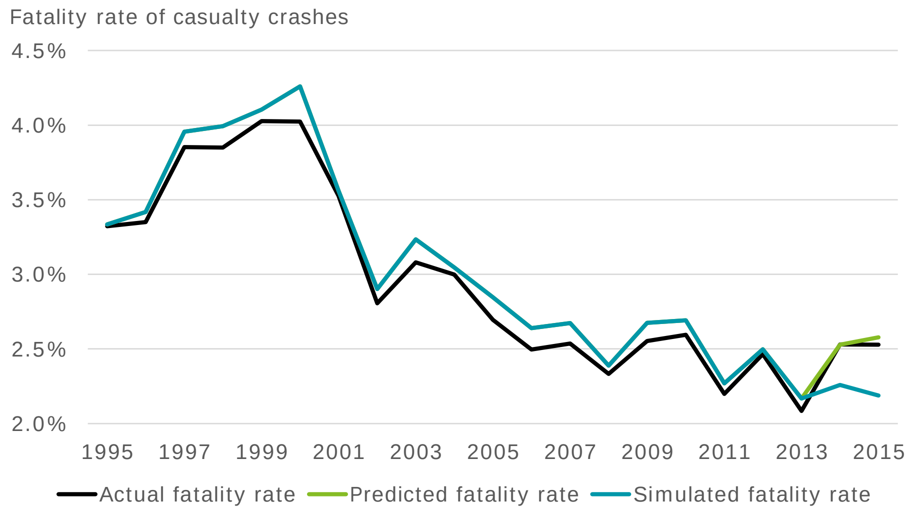
available about how these factors differ across regions, making it difficult to draw meaningful or robust conclusions and implications from them.

Whilst there are some differences in the likelihood of fatalities, results in Table C.4 suggest there is mixed significance (noting that standard errors were not calculated for the marginal effects in Table C.5, due to computational limitations).

As with models of the weekly number of casualty crashes, it is possible to simulate the injury severity model in order to better understand drivers behind the 2014/15 uptick in the *rate* of injury severity per casualty crash. The expected proportion of casualty crashes that result in a fatality are calculated, setting the time period indicator to 2013. This is designed to disentangle time trends from changes in the underlying factors that cause a given severity level.

Presented below, the simulation results suggest that the uptick in 2014 and 2015 in the fatality rate was not driven by changes in the observable characteristics of crashes (such as gender, region, speed limit, and contributing factors). Instead, a large proportion of the increase is attributable to the time period indicators. This suggests that the uptick was driven by changes outside of the micro factors leading to injury severity.

Chart C.3 : Severity model simulation

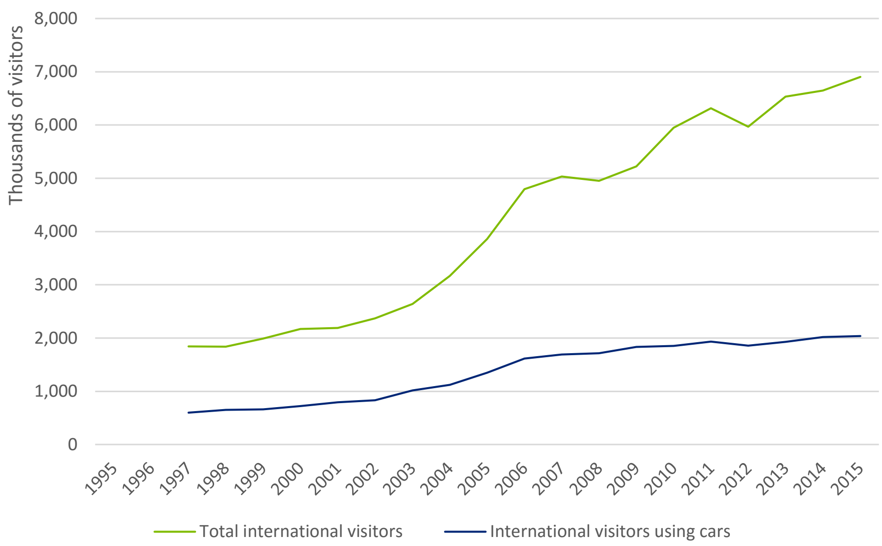


Appendix D : Other descriptive analysis

D.1. Overseas licence holders

Since 1997, the number of international visitors to New Zealand has increased from 1.8 million to 6.9 million in 2015 (an average annual growth rate of 7.6%; Chart D.1). Over that same period, the use of cars by international visitors has also increased, from 600,000 in 1997 to 2 million in 2015, but at a slightly slower rate (7% average annual growth).

Chart D.1 International visitors and use of cars (self, family, friends and company owned and rental cars)



Source: Ministry of Business, Innovation and Employment

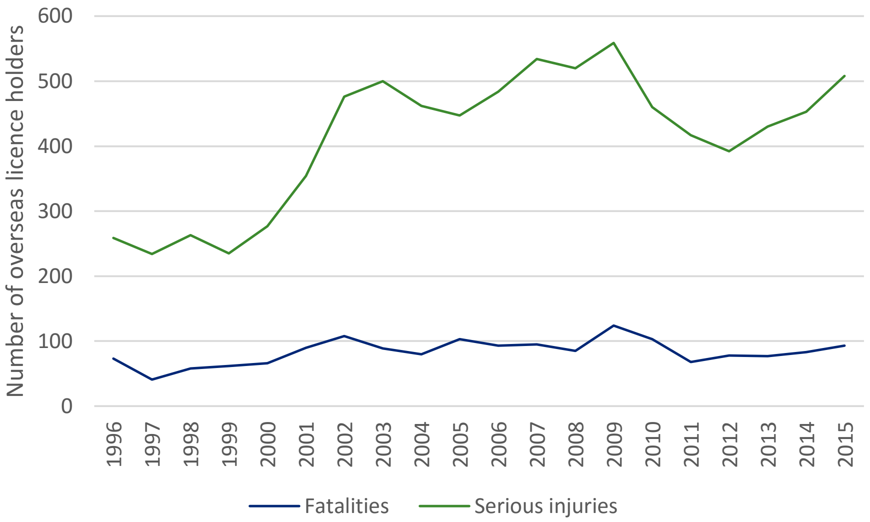
The increasing use of cars by overseas licence holders, all else equal, should translate to increased exposure to crash risk. However, it is unclear:

- the distances that overseas licence holders drive, relative to total vehicle kilometres travelled; and
- whether overseas licence holders are at a higher risk of crash (for a given unit of travel) because they are unable to adapt to New Zealand road rules and conditions.

Together, this means that disentangling the impact of overseas licence holders on the road toll is a complex task. Whilst the number of overseas licence holders involved in casualty crashes has increased over time (Chart D.2), this is within the context of increasing visitor numbers.

Notably, whilst there has been an increase in the number of overseas licence holders seriously injured since 2012, the number of fatalities has remained relatively stable, suggesting that increases in the number of overseas licence holders has not necessarily driven increases in New Zealand's road toll.

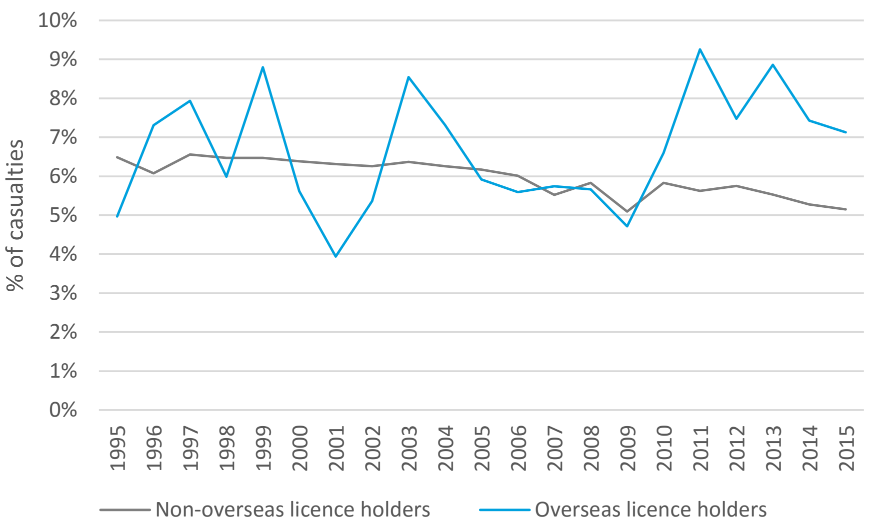
Chart D.2 Number of overseas licence holders seriously or fatally injured



Source: CAS

However, overseas licence holders may be more susceptible to crashes, if they are less likely to be able to successfully adapt to New Zealand road rules and conditions. Chart D.3 shows the share of casualties where failure to give way was a contributing factor for overseas licence holders, and non-overseas licence holders.

Chart D.3 Casualties where failure to give way was a contributing factor, as share of casualties



Source: CAS

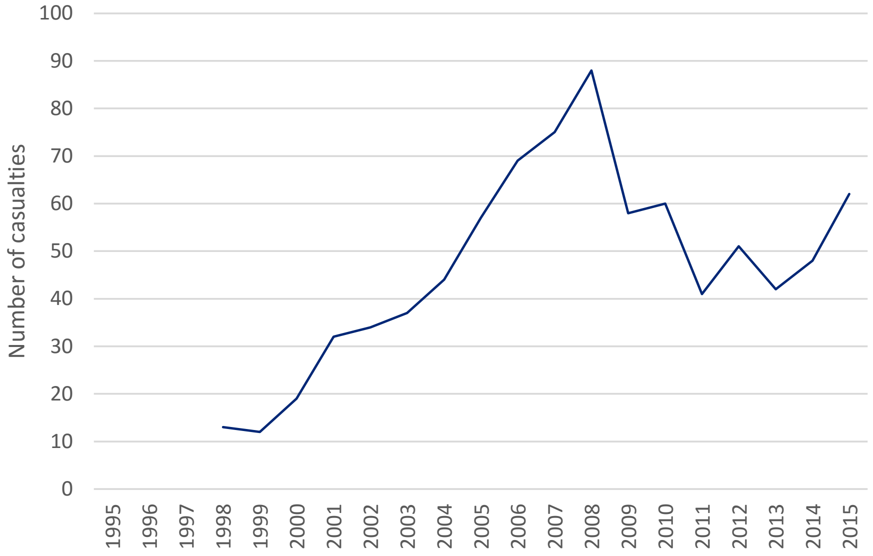
Casualties for overseas licence holders are proportionately more likely to have involved a failure to give way, particularly since 2010. This is a somewhat counterintuitive result, given the simplification of give way rules in New Zealand in 2012, to align with many other countries. However, it may be the case that the reduction in crashes from these rule changes

impacted on crashes that did not cause an injury – and hence have not had an impact on the crashes recorded in CAS.

D.2. Distractions

The number of casualty crashes where distraction by mobile phones and other devices has changed dramatically over time, with the rate trending upwards from 1998 to 2008 (Chart D.4), coinciding with the penetration of mobile phones in the population.

Chart D.4 Casualties where distraction by mobile phones and other devices were a contributing factor.



Source: CAS. Note: Contributing factors 359 (Cell phone), 361 (Navigation device) and 362 (Non cell communication device) are included here.

In 2009, the Land Transport (Road User) Amendment Rule 2009 came into effect, which banned the use of hand-held mobile phones and all texting whilst driving. This is associated with a significant drop in the number of casualties where phones and devices were a factor (from 88 in 2008 to 58 in 2009).

However, in recent years, the number of instances where devices were a factor has risen (to 62 in 2015), which may be driven by the increasing use of mobile phones for navigation, the changing nature in which individuals use their mobile phones whilst driving, and changing attitudes of drivers.

Limitation of our work

General use restriction

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