An analysis of potential factors behind the 2011 reduction in New Zealand road fatalities

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Executive Summary

The New Zealand road toll for 2011 showed a dramatic decrease from previous years. This large 24% decline, from 375 in 2010 to a provisional 284 deaths, is unprecedented as a year-to-next-year drop (in percentage terms). With the aim of better understanding what may have led to such a marked drop in 2011 deaths and what the factors are that drive the road toll in general, this report first looks at analyses of road toll reductions in other jurisdictions to help inform methods and approaches appropriate to New Zealand. Second, we analyse data showing how driving patterns have been changing over the past decade to identify evidence of unusual changes recently. Third, we carry out econometric analysis of time series data on traffic crashes and casualties in terms of economic, social and exposure variables that potentially explain at least some of the changes in casualties.

New Zealand is not alone internationally in experiencing record low road tolls in recent years. Reductions in certain higher risk forms of travel have been identified as important factors in these road toll declines overseas. The literature scan showed that, internationally, unemployment driven economic factors can have a marked impact on youth and rural related fatalities. Associated with the effects of the economic recession, some countries' road fatalities have fallen presumably because of reduced driving in the following conditions: rush hour; long distance leisure; heavy trucks; driving by young people (resulting in disproportionately fewer casualties). However some categories of casualties increased, including: motorcyclists; pedal cyclists; leisure driving on local roads; crashes associated with alcohol consumption. Many countries have experienced large drops in their road tolls, without any clearly identified explanation apart from exposure reduction (due to the economic recession and weather events) and overall downward trend associated with a generally improving road safety environment. Most of these drops are being sustained, although those caused by one-off unusual events (e.g. severe weather) have seen a regression to the mean.

The changes in particular casualty types found in the analyses of road deaths from countries with much larger populations than New Zealand are important in showing the potential effects of economic factors. However similar analytical approaches cannot be used for the New Zealand data as the numbers within given casualty classes are generally too small to show reliable trends. An advantage for the New Zealand analysis is the availability of a large number of data sources (on travel volume, on-road speeds, alcohol use by drivers, etc) that can help identify underlying factors. Our analysis of these data sources showed a generally improving road safety environment over the past decade without any apparent major changes from 2010 to 2011 that could feasibly account for an important proportion of the 2011 road toll drop.

The purpose of the econometric analysis was to model the way that road deaths have changed over time and whether potentially causal factors measured over the same period appear to explain variation in the counts of road deaths. The objective was not to explain the longer term downward trend in road deaths. Rather it was to see whether any particular factors played a major role in the marked downward departure from the trend in 2011. Statistically significant factors that were found to be associated with the changes in road fatalities over the past decade (separate to the long run trend) included: changes in the real petrol price index; changes in real product wages; changes in motorcycle registrations.

In summary, our modelling split the drop of 91 fatalities in 2011 (compared with 2010) into three components:

- 20 fatalities explicable by a return to the long run trend.
    - This included both the trend of 10.4 fewer deaths per year, and also that 2010 fatalities were slightly above what was expected from modelling the long run trend.
- 21 fatalities explicable by three factors explaining quarterly variation around the long run trend to a statistically significant degree (changes in the real petrol price index; changes in real product wages; changes in motorcycle registrations).
- 50 fatalities not yet explicable.
    - This results from some combination of random variation and events or policy changes that are unique to 2011 that we cannot yet model. A substantial effect of purely random variation is plausible for this sort of time series data; but, over time, the effects of other factors may be able to be estimated from the model.

Section 1: Background – international experience of road toll trends

Introduction

We performed a scan of the recent literature, key articles and web resources in order to understand what factors have been related to large road toll drops in other motorised countries. This scan is crucial to understanding which methodological approaches should be adopted and what factors to look for in explaining the road toll decline.

Large changes in road injury, especially among fatalities, have been investigated for decades across the globe. A scan of the recent literature reveals a substantial body of work from the 1980s associated with the sharp declines thought to be related to the global recession of 1981-1982 (Joksch, 1984; Partyka, 1984; Wagenaar, 1984). The 2008 downturn has in turn seen many recent reports and papers published about the large drops in US road fatalities (Longthorne et al, 2010; Rakauskas et al, 2009; Sivak, 2008; Sivak, 2009; Sivak and Schoettle, 2010a; Sivak and Schoettle, 2010b; Weijermars et al, 2010), in Europe (Elvik, 2010; Kopits and Cropper, 2008; Weijermars et al, 2010) and elsewhere (Hagiwara et al, 2010).

There is also another closely related body of literature that has looked at long-term patterns and trends driving national road tolls (Elvik, 2010; European Road Safety Observatory, 2007; Law et al, 2011; Litman and Fitzroy, 2010; Page, 2001; Partyka, 1984; Partyka, 1991; Prato et al, 2011; Sze, 2008). From these types of studies, many important factors have been identified with the potential for long-term and also relatively short-term impacts on road toll trends.

Some recent analyses have been undertaken of large reductions in road tolls in other countries. These are very relevant to New Zealand as economic factors (the economic recession and increases in petrol prices) are widely assumed to have played an important role in reducing certain forms of exposure to crash risk. Table 1 lists some of these studies and summarises the findings.

Amount of travel

Probably the most important factor within economically developed countries influencing fatality rates is the strong positive relationship between per capita vehicle travel (i.e., population mobility) and the rate of traffic deaths (Litman and Fitzroy, 2010; Martensen et al, 2008). This comes as no surprise since per capita vehicle travel is one of the best exposure indices in the road safety field. While most mobility trends are gradual and long term, they can occasionally change over the course of days, weeks and months on both large and small geographic scales due to large-scale weather events, natural disasters, economic patterns, petrol prices, and petrol availability, among other contributing factors.

Within a country, separate patterns can and do emerge. Recently a weighted approach (among drivers only) was used to control for vehicle distance travelled exposure focused on geographic areas in order to prioritize road safety interventions by location (Kim et al, 2012). The strongest independent risk factors for driver death attributable to crashes they identified were alcohol and drug use, speed limit ≥45 mph, adverse weather conditions, non-divided highways, vehicle type, vehicle defects, roadway location, and rural roads.

The rural risk issue is well known. According to Litman, "…distance travelled has a stronger effect on fatalities in rural conditions, probably due to factors such as increased traffic speeds, emergency response time, less seatbelt and helmet use, and more higher-risk driving (such as young drivers) due to fewer transport alternatives"(Litman and Fitzroy, 2010). Rakauskas et. al. (2009) also offered additional (and overlapping) explanations for higher rural risks including less safe roads, differences in vehicle types (e.g., utes versus passenger vehicles) and amounts of driving under the influence. Favourable urban fatality per distance results are related to slower speeds due to increased congestion and lower speed limits. In turn, this leads to the well-known paradox of increased rates of urban crashes but lower average severity. These findings help explain why small changes in rural driving can have proportionally large impacts on the road toll.

Table 1: Key recent studies analysing changes in the road toll in other countries

Authors	**Jurisdiction and time period**	**Methods used**	**Key factors found**
Weijermars, Bijleveld, Stipdonk (2010)	Netherlands, 2004 (to study marked drop in fatalities 2003-2004)	Regression models fitted to counts for different groups of casualties and drivers	1. Moped ownership and the number of mopeds sold went down in 2004. 2. Alcohol use by (18-24 and 40-49 year-old) car drivers decreased in 2004. 3. Seat belt use increased in 2004. 4. The speed that is exceeded by 10% of the vehicles on 100 and 120 km/h roads decreased between 2003 and 2005. 5. Car ownership by 18-24 year-olds was lower from 2004 than in the years preceding 2004. This may indicate a mobility shift for young novice drivers. 6. The penetration of ESC and airbags in the entire vehicle fleet increased in 2004. The first four factors together are responsible for a decline of 55 road fatalities between 2003 and 2004. The fifth factor may have resulted in a decline of at most fifty road fatalities between 2003 and 2004. This factor may possibly be an explanation for the high number of road fatalities in 2003 in comparison with the trend. Together with statistical fluctuations and a trend-wise decline of the fatality rate, these factors may together be an explanation for approximately three-quarters of the decline in road fatalities between 2003 and 2004.
Sivak, Schoettle (2010a)	From 2005 to 2009, US road fatalities (dropped by 22%)	Comparison of data for 2005 with 2008 (the latest year for which detailed data were available), looking for largest changes.	Rush hours **Down**. Decreased commuter travel Interstates **Down**. Reduced long-distance leisure travel Local roads/streets **Up**. Increased local leisure travel Side crashes **Down**. More side air bags Deployment of side air bags **Up**. More side air bags Seats with no air bags **Down**. More air bags Frontal crashes **Down**. Decreased speeds; more seats with front air bags; improved air bags Roads with higher speed limits **Down**. Decreased speeds No avoidance manoeuvre **Down**. Decreased speeds Construction zone **Down**. Reduced road construction Multiple fatalities per crash and per vehicle **Down**. More air bags Motorcycles **Up**. Increased ownership (1) by middle-aged men and (2) of larger motorcycles Heavy trucks **Down**. Reduced freight shipments Reported alcohol use **Up**. Increased alcohol consumption; increased DWI enforcement

			Repeat DWI offenders **Down**. Disproportionate reduction in driving by repeat DWI offenders Repeat crash involvement **Down**. Decreased alcohol involvement; fewer high-risk drivers on the road Reckless driving **Down**. Decreased speeds Drowsy driving **Down**. Disproportionate decrease in long-distance leisure driving Inattentive driving **Up**. Increased complexity of daily lives; increased distractions; increased coder sensitivity to the issue of distractions Young drivers **Down**. Fewer young drivers on the road; increased use of graduated licensing Jaywalking **Down**. Decreased speeds
Longthorne, Subramanian, Chen (2010)	US road toll 2007-2008	Comparison by casualty type	Fatalities involving drivers: - aged between 16-24 fell 17% - between the ages of 25 to 44 decreased by about 11% - between 45-64 years old decreased by about 10% - those 65 years old and older decreased by about 7%. Child fatalities (under 16 years old) decreased by about 20%. Multiple-vehicle fatalities decreased by about 13% Fatalities involving large trucks (decreased by about 12%) Crashes that occurred during the weekend (decreased by about 11%) Occupant fatalities in vehicles that rolled over in multiple-vehicle crashes (decreased by about 19%) Motorcyclist and pedal cyclist fatalities showed an increase in 2008. The long-term declining trend can be attributed to crashworthiness and crash avoidance measures, through the issuing of Federal Motor Vehicle Safety Standards, roadway improvements, as well as commercial vehicle programs. In addition the recession in the US economy has contributed.

Macro and time period economic effects

Economic effects are important cross-sectionally, as well as over time, because income has a high correlation with car ownership and use (de Place and Rood, 2011). The cross-sectional picture shows how vehicle ownership can plummet below a certain income threshold, emphasising that at certain points, especially among poorer households, small changes in income can have a large impact on vehicle ownership, and thus car use and exposure. This in turn may reduce levels of community exposure to motor vehicle crashes or lead to mode shift to safer (public transport) or riskier (motorcycles) travel modes.

Over time, US recessions have been consistently associated with 5-15% reductions in fatal crashes of young drivers (Longthorne et al, 2010). The mediating effects are thought to act in part through higher unemployment (especially among youth and the poor), cost of petrol, and affordability of petrol. Lower youth employment means less need to travel and lower affordability of travel (running costs, ownership, and maintenance) among the group with the highest crash fatality rate. We know too that rural/leisure traffic goes down during recessions which is also higher risk driving and it is likely that this young age group reduces much of its discretionary leisure travel (Longthorne et al, 2010). Longthorne et. al. also showed that fatality declines during the latest US recession were more likely to occur in geographic areas with higher rates of unemployment and weekend travel.

Since economic factors tend to have a greater effect on those who are at higher crash risk, small negative changes in economic conditions may lead to leveraged reductions in crash/injury rates. "In particular…" according to Longthorne, "… the fatality drops in these time periods were especially similar when looking at crashes involving young drivers of passenger vehicles and crashes involving more than one vehicle". This argument is supported by the US findings that reductions in vehicle miles travelled (VMT) were much less significant than the overall decline in fatalities (Longthorne et al, 2010; Sivak, 2009).

Sivak and colleagues have also explored the most recent recession's effect in the US on various changes in the patterns of fatalities (Sivak, 2009; Sivak and Schoettle, 2010a; Sivak and Schoettle, 2011) showing less driving and different proportions of leisure and night-time driving. Recent reports from Greece, which has been severely affected by the economic crisis (youth unemployment rose from 18.6% in May of 2008 to 40.1% in May 2011), have revealed marked reductions in alcohol consumption and drink-driving arrests (Kentikelenis et al, 2011). Changes in the number of arrests may not only reflect changes in driver behaviour but also changes in police enforcement.

The IRTAD (International Traffic Safety Data and Analysis Group) report on the international road safety environment highlights the recent economic recession as a key factor in the sharp reductions in many countries' road tolls, without identifying clear causal pathways:

> "In several countries — for example, the United States, Hungary, Ireland or Denmark — we observed a more pronounced reduction in the number of fatalities during the last 3-4 years than during the preceding 15 years. We have no real explanation for such acceleration in the trend. Several countries suggested that the economic crisis which began in 2008 may have had an impact on these positive road safety developments through a variety of effects (a decrease in mobility, less traffic by heavy vehicles, less [sic] inexperienced drivers with relatively higher risks, a reduction in leisure driving, safer driving behaviour, etc.). Up to now, we were not able to

come up with a scientifically satisfactory explanation and no-one was able to quantify its impact on road safety. Many European countries also identified the severe winter conditions at the end of 2010 and beginning of 2011 as a contributing factor. Finally, most countries now have road safety strategies in place, with well-defined and targeted measures, which have borne fruit over the last few years." (IRTAD, 2012)

Figure 1: Short-term changes in road fatalities 2010 compared to 2009 (IRTAD, 2012)

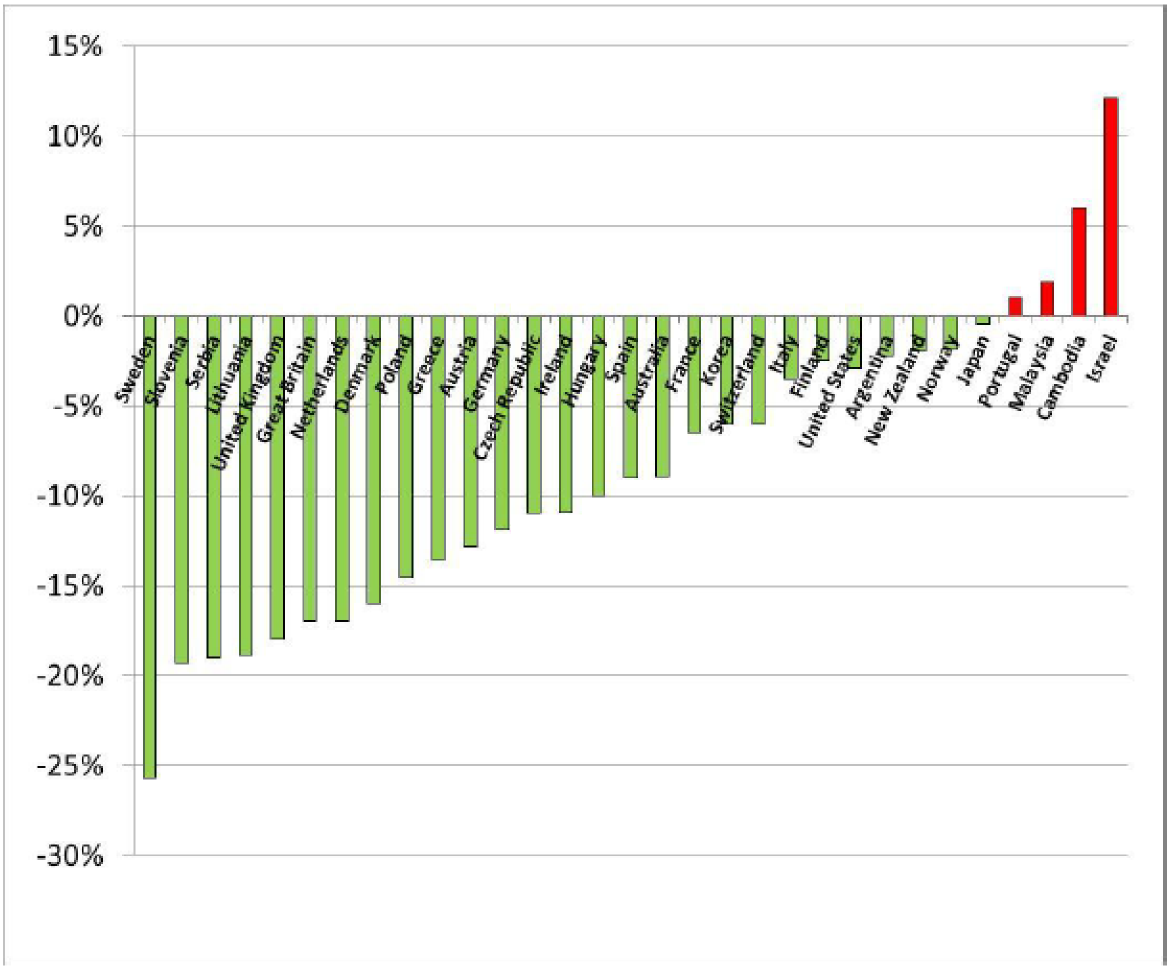


Figure 1 shows that the vast majority of countries surveyed by IRTAD had drops in their road toll in 2010 compared to 2009. In Australia, the national road toll last year fell to its lowest level since 1946 (Ministry of Infrastructure and Transport, 2012). In total, 1292 people were killed on Australia's roads in 2011, down 4.4% compared with 2010 and down almost 20% from five years ago. All states experienced a reduction in their road toll in 2011 except Queensland, which increased from 249 to 269, and Victoria, which was steady at 288. Deaths of road users in the high-risk 17 to 25 age bracket decreased more than any other age group in 2011 compared with the previous year, falling 17% from 336 to 279.

The US experienced its lowest ever rate of road deaths per km driven, improving even beyond the highly significant falls in road deaths seen since 2008. Passenger car crashes fell, as did those involving alcohol. However, crashes involving heavy trucks, motorcycles and pedestrians all increased from the previous year.

IRTAD reports international road safety trends, although the data available at the time of writing refer mostly to data up to and including 2010 (IRTAD, 2012). Countries experiencing sharp drops in their 2010 road toll compared to 2009 include many northern European countries that were affected by particularly severe winter conditions, which constrained travel and vehicle speeds. These weather effects enhanced existing effects of both road safety policy and the effects of the economic recession to produce some very low road tolls.

Age and population effects

While the economic effects on young drivers are well established (see page 10), how it impacts on the other end of the age spectrum, the elderly, is less clear. The elderly are also a high risk group in terms of fatalities per kilometre travelled, at least in part due to their fragility, but they are low in numbers and in total distance driven. As they drive less, their risk per licensed driver is not high (Keall and Frith, 2004). Employment status is not as important to their continued driving so they may be more resilient to short-term downturns, but elderly drivers on fixed incomes may be more susceptible. Aside from the effect of economic downturns though, long-term trends in the elderly fatal crash risk have been somewhat surprising. According to a recent US study, "Contrary to expectations based on increased licensure and travel by older drivers, their fatal crash risk has declined during the past decade and has declined at a faster rate than for middle-age drivers...the current analysis indicates that the reduced fatality risk of older drivers reflects both less likelihood of being involved in a police-reported crash and greater likelihood that they will survive when they do crash (Cheung and McCartt, 2011)."

Cohort effects

Although not as well studied, cohort effects, usually defined by age cohorts, can ripple through the demographic pyramid over time to impact on road fatality rates. In Japan, Hagiwara reported that, "cohorts had a strong effect on changes in the number of fatal accidents. However, cohort had little effect on changes in the number of injury accidents. The cohorts born in 1967-71 and 72-76 have a large increasing effect on the number of fatal accidents, and the latest cohort born in 1982-86 has a large decreasing effect" (Hagiwara et al, 2010). As recent IPRU research has shown, age cohorts play an important role in motorcycle use and fatality patterns as well.

Number of occupants and type of vehicles

Another important factor that can vary over time and among age groups is the number of occupants in a vehicle. In a recent study, Mike Males showed that a large influence on higher teen fatality rates was the very fact that they were more likely to carry passengers, usually other teens (Males, 2009). "More vehicle occupants was the biggest predictor of [young] drivers' higher fatal crash rates, accounting for 30% of the total variance and 87% of the explained variance. Smaller vehicle size and older vehicle age were also significant though small predictors of higher fatal [teen] crash rates."

Single versus multiple vehicle crashes

A change in single versus multiple vehicle crashes has been explored within sharp fatality declines. Looking at declines in the Netherlands in 2004, Weijermars et. al. showed the decline to be driven by "pedestrians, (light) moped riders and car occupants; male and 18-24 year-old and 40-49 year-old car drivers; car drivers who are involved in single vehicle crashes" (Weijermars et al, 2010).

Limitations of time-series analysis to identify causal factors and predict future rates

With some important exceptions, time-series analyses have often proved disappointing when applied to the analysis of road crash and injury rates. This is thought to be largely because the analyses fail to account for the most important factors influencing the road toll: road user behaviour and type of exposure. Elvik (2010) examined the stability of long-term trends in the number of traffic fatalities in eight different countries where the number of traffic fatalities reached a peak around 1970–1972 and since declined. It was concluded that the trends towards fewer fatalities in the countries selected was not stable and that even trend lines that fit past observations very closely do not lead to accurate prediction of future rates. The chief lesson was that past trends do not provide a reliable basis for predicting future developments with respect to the number of traffic fatalities. Elvik identified the omission of important variables as the main deficiency in these analyses, in particular variables that describe road user behaviour (speed, drinking and driving, seat belt wearing, compliance with other provisions).

Lessons for analytical approaches

The changes in particular casualty types found in the analyses from countries with much larger populations than New Zealand are important in showing the potential effects of economic factors. However similar analytical approaches cannot be used for the New Zealand data as the numbers within given casualty classes are usually too small to show reliable trends. An advantage for the New Zealand analysis is the availability of a large number of data sources (on travel, on-road speeds, alcohol use by drivers, licensing data, etc.) that can help highlight underlying factors.

Section 2: Travel patterns and related data

Introduction

The changes in particular casualty types found in the analyses of road deaths from countries with much larger populations than New Zealand are important in showing the potential effects of economic factors. However similar analytical approaches cannot be used for the New Zealand data as the numbers within given casualty classes are generally too small to show reliable trends. An advantage for the New Zealand analysis is the availability of a large number of data sources (on travel volume, on-road speeds, alcohol use by drivers, etc) that can help identify underlying factors. Our analysis of these data sources, explained below, showed a generally improving road safety environment over the past decade without any apparent major changes from 2010 to 2011 that could feasibly account for an important proportion of the 2011 road toll drop. The main data sources we used for this analysis are listed in the Appendix.

Some possible explanations for the 2011 drop in brief

A tempting approach to analyzing the road toll drop is to look for a single factor changing markedly between 2010 and 2011 as the main contributor to the 2011 change. Table 2 addresses this simple approach to briefly describe why certain plausible factors cannot be considered as explaining most of the 2011 road toll drop (without discounting them as possible *contributors* to a reducing road toll).

Table 2: In brief—Reasons why selected factors do not largely explain the 2011 road toll drop by themselves

Factor	**Reasons this factor is unlikely to explain most of the drop**
Less driving (e.g. because of recession)	Traffic was down only 1.2% in 2011 compared with 2010 (see page 16), whereas the fall in road toll was 24%.
Recession has dramatically changed economic behavior and hence somehow reduced risky travel behavior (e.g. by reducing alcohol and drug spending)	The fall in the road toll is too late for this to be plausible. Recession impacts were clear by 2009 (e.g. heavy traffic clearly fell then, see Figure 3 on page 17). Other countries show reductions in road toll that are much more coincident with the timing of the recession.
Christchurch earthquake reduced Canterbury travel	The Canterbury toll is not dramatically different from previous years. Admittedly, the Canterbury road toll of 34 in 2011 is 14 fewer than in 2010 (48), but it is actually more than their road toll in 2009 (32).[1] More formally, the Canterbury road toll of 34 in 2011 is almost exactly what one would expect for Canterbury given its fatalities from 2007 to 2010 assuming that it has exactly the same drop in 2011 as occurred nationwide (the expected value is 33.8).
The Christchurch earthquake reduced risk-taking on the road nationally	It would be expected that the effects of the earthquake would be most pronounced in the area most affected (Canterbury), for which there is no evidence (see above). An analysis of common risk-taking behaviours as factors in crashes (see Figure 9 and Figure 10) does not suggest much change from 2010 to 2011 in the proportion of crashes

[1] Source: Ministry of Transport (Quarterly report 2011Q4 v1.xlsx)

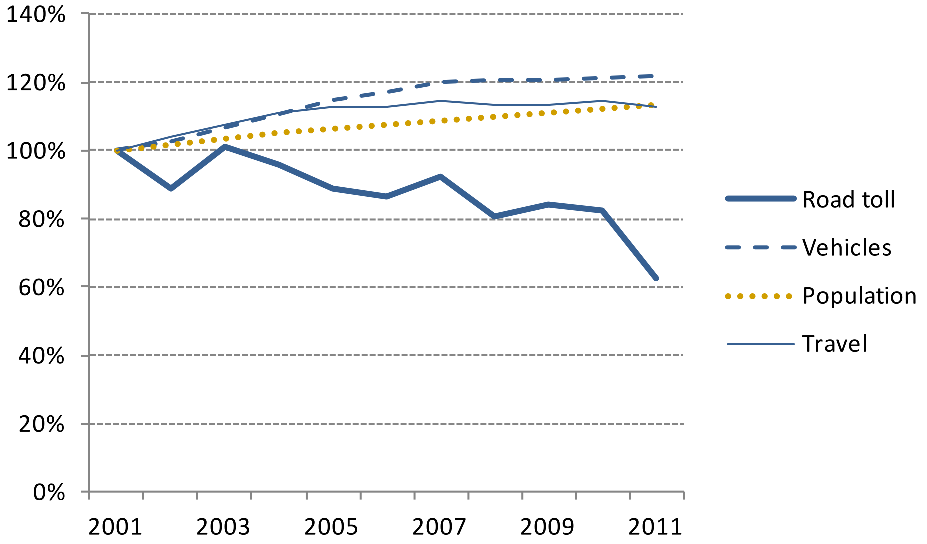
	involving excessive speed and alcohol.
Special initiatives in particular regions caused dramatic drops	Some regions (particularly Northland) showed greater falls in 2011 than others. But overall, the differences between regions in terms of the size of changes in 2011 were not large enough to be clear evidence of systematic differences between regions rather than mere chance fluctuations.[2]
Fewer holiday weekends (Waitangi Day on Sunday, and Anzac Day overlapped with Easter Monday)	Changes in deaths associated with two such weekends are far from the drop of 91 deaths. For example, Queens Birthday weekend in 2010 had only 1 death. The longer Easter holiday weekend[3] averaged 6 deaths each year between 2000 and 2010; so the increase in deaths to be expected if we had had two more long weekends in 2011 (compared with two-day weekends) is clearly much smaller than 91. This may have made a contribution to the drop, but it is small.
4 km/h speed tolerance around holiday weekends	The Police began enforcing a 4 km/h speed tolerance during holiday weekends during Queen's Birthday weekend 2010 (following a very high Easter holiday road toll that year).[4] This may well contribute to reduced holiday road tolls over time given the well-established relationship between speed reductions and fatalities. For example, a 5% reduction in mean speed on the open road is typically associated with a reduction of around 20% in fatal accidents (OECD, 2006). However, we do not see this as a major explanation of the drop between 2010 and 2011 because there was little change in the proportions of crashes occurring in holiday weekends and such crashes form a small percentage of all crashes (see Figure 9 and Figure 10). In 2011, there were 35 fatalities during the four main holiday periods (Christmas/New Year, Easter, Queen's Birthday, Labour Day), only one fewer than in 2010 (and similar to the average of 33 for the previous five years).
SuperGold cards: Older drivers now using public transport in cities instead of driving	Timing of this factor as a major influence is implausible. The SuperGold card scheme started in late 2008. SuperGold boardings in 2011 were only 4% higher than in 2010.[5]

Trends in travel volume, vehicle numbers, and population

The road toll has been trending down over time, despite increases in population, vehicle numbers, and road travel (Figure 2).

[2] We compared the numbers of fatalities for 14 regions in 2011 to the numbers expected statistically (derived by using regional numbers of fatalities 2007–2010 and assuming all regions had an identical rate of decrease in 2011). Regional differences were not significantly greater than expected from random fluctuations.
[3] www.transport.govt.nz/ourwork/land/landsafety/holidayroadtoll/
[4] www.police.govt.nz/news/release/28282.html
[5] Derived from monthly data supplied by the NZ Transport Agency.

Figure 2: Road toll and related trends (2001=100%)



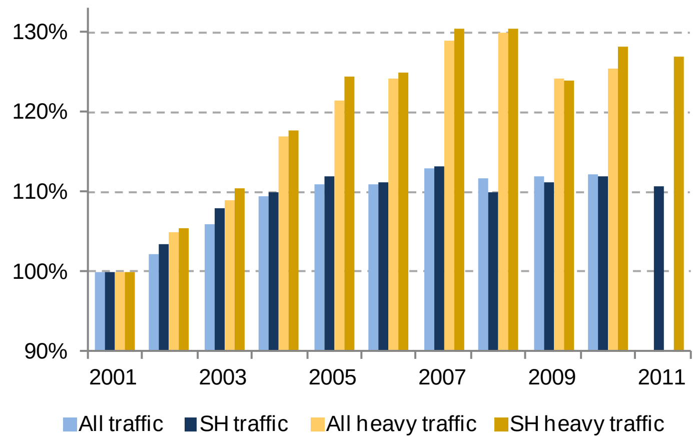
Source: Adapted from *Quarterly road toll report* (Ministry of Transport, 2012). We extended the Travel data series to 2011 by using state highway travel data from NZ Transport Agency.

In particular, a drop in distance travelled on roads is not a major explanation of the fall in the road toll in 2011. The State Highway Traffic Volume growth indexes show a decrease of only 1.2% for all vehicles (and 1.0% for heavy vehicles) in 2011 compared with 2010 (NZ Transport Agency, 2012). Of course, not all road travel is on state highways. But given that more complete distance data from vehicle odometer readings is not yet available for all of 2011, we checked that changes over the years in the level of state highway traffic parallel those for total traffic closely (Figure 3). Besides, vehicle odometer data is available up to the end of September 2011 and it shows a fall of around 0.5% compared with the same nine months in 2010.

Of course, some vehicles are associated with greater risk; in particular, deaths from crashes involving trucks make up around 15% of the total road toll, while only about 6% of the total distance travelled on NZ roads is travelled by trucks.[6] But odometer data available confirms there was no major fall in heavy traffic in 2011; specifically, odometer data up to September 2011 shows a small increase of 2% (compared with the same months in 2010).

[6] www.transport.govt.nz/research/truckcrashfacts/

Figure 3: Growth in traffic (2001=100%)



Hospitalisations resulting from vehicle crashes

Figure 4 shows trends in hospitalisations that differ somewhat from the pattern of fatalities. Hence over the last decade, fatalities have fallen from being around 15% of hospitalisations greater than one day to around 12%. But there does not seem to have been a particular change in this pattern in 2011; hospitalisation data available for the first half of 2011 shows a fatality to hospitalisation proportion of 12%, very similar to the average for the previous five years. There is also a noticeable increase in hospitalisations for motorcyclists from 2006 that follows increased purchases of motorcycles starting around then, reflected in the larger motorcycle fleet as shown in Figure 5. Although mopeds are commonly included in 'motorcycle' crash statistics, we note that moped fatalities are comparatively rare (only 4 in the six years from 2005 through 2011 compared with 258 motorcyclist deaths).

Figure 4: Hospitalisations over 1 day as a result of vehicle crashes (rolling 12 month total from 2001 to mid-2011)

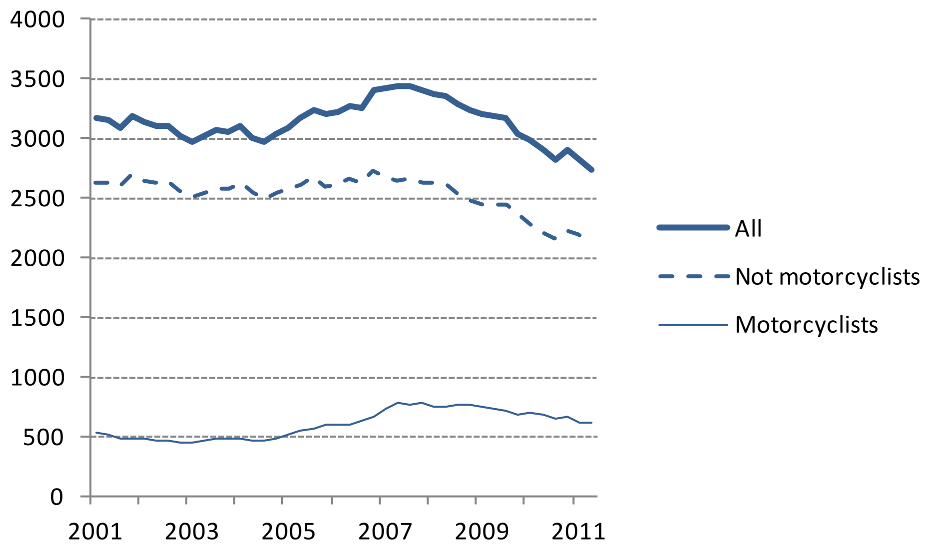
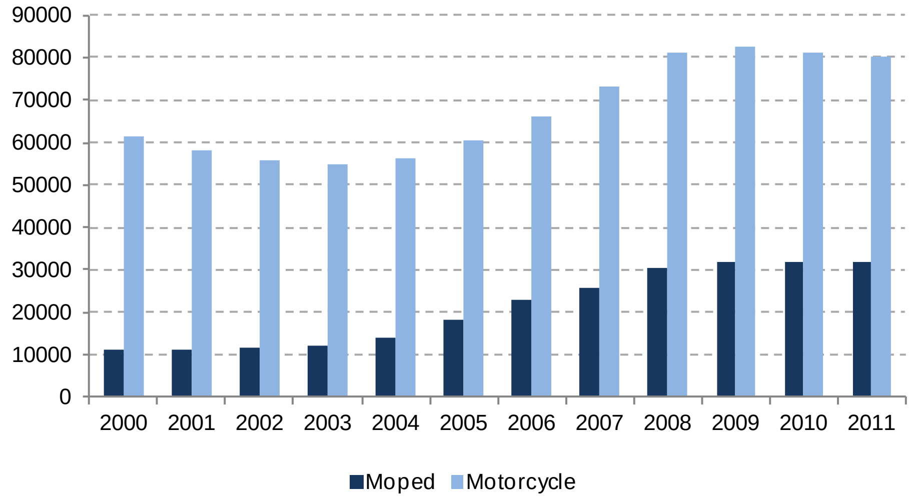


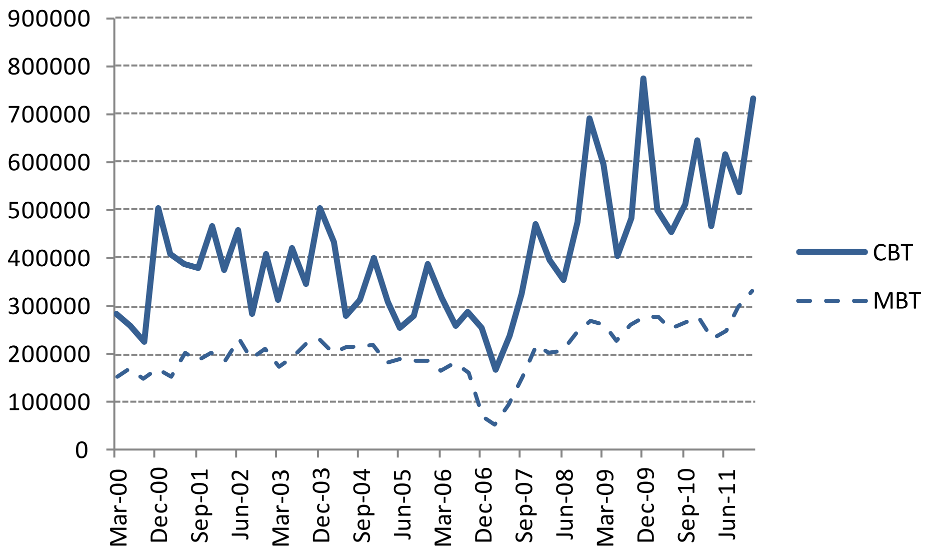
Figure 5: Motorcycle/moped fleet size



Trends in drink driving

As is well known, the extent of drink driving can affect the road toll. Roadside alcohol surveys show a clear fall in drink driving between 1995 and 2005, but a flattening after that (Ministry of Transport, 2010b). We do not have this direct measure of the level of drink driving for 2011 because the roadside surveys are only done every second year. But we do have data on related enforcement activity: the number of breath tests done. Apart from the regular increases in such tests around Christmas/New Year, Figure 6 shows a clear increase in breath testing in recent years after a marked decrease in 2006/07. There was no particularly dramatic change in 2011, although mobile breath tests did reach their highest quarterly level ever at the end of 2011.

Figure 6: Compulsory (CBT) and mobile breath test (MBT) numbers (quarterly)



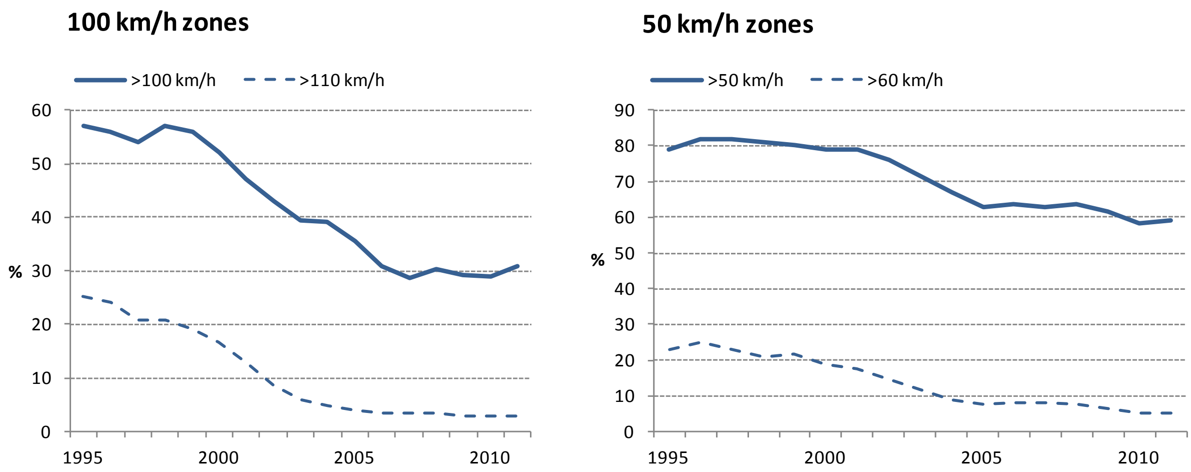
Trends in speed

Speeds did not decrease markedly in 2011, or even over the years immediately before. Rather, the main decreases in proportions of drivers exceeding the speed limit occurred several years earlier

(Figure 7). Mean vehicle speeds measured by speed surveys have changed little in the past five years (less than 0.5 km/h in 100 km/h and 50 km/h zones).

These results are based on annual speed surveys conducted at randomly selected sites around New Zealand.[7] There are about 65 open road and 65 urban sites surveyed each year. Annual speed surveys are designed to monitor changes in free speeds of vehicles in both 100 km/h speed limit areas and main urban 50 km/h areas. Free speeds are speeds attained when the vehicle is unimpeded by the presence of other vehicles (i.e. there is some distance between a vehicle travelling at a free speed and the vehicle in front of it) or by environmental features such as traffic lights, intersections, hills, corners or road works. By monitoring the speeds of unimpeded vehicles this survey measures driver choice of speed.

Figure 7: Percent exceeding speed limits



Trends in safety belt wearing

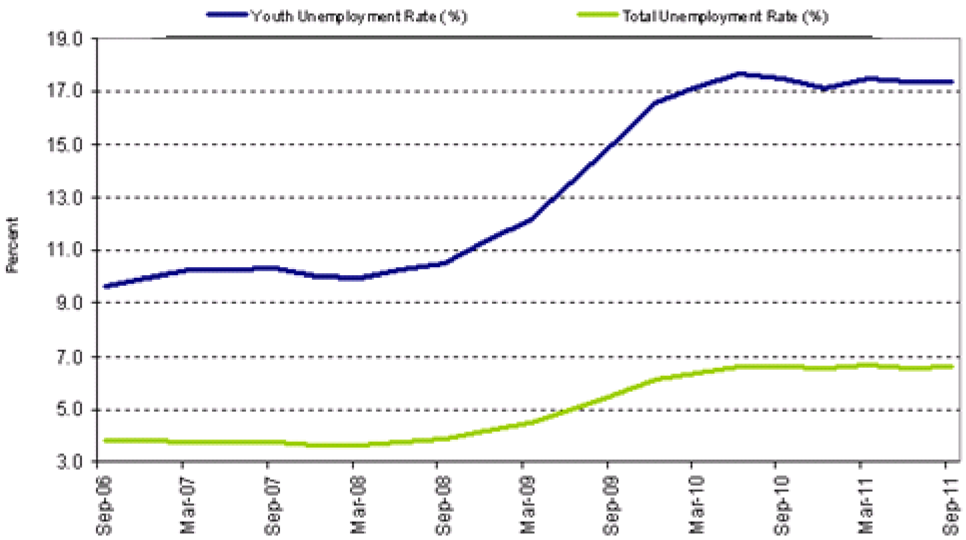
Similarly, major gains in some other safety-related behaviours were clearly made in earlier years. For example, safety belt wearing rates for front seat adults were 96% in 2011 but have been 95% or 96% every year since 2005.[8]

Economic trends

The recent financial crisis began to have impact in late 2008, and the effects on employment seem to have peaked well before the start of 2011 (Figure 8). Note too that the unemployment rate is particularly high for younger age groups, a high-risk group for driving, but again this turned upwards well before 2011.

[7] www.transport.govt.nz/research/SpeedSurveys/
[8] www.transport.govt.nz/research/Pages/Safetybeltstatistics-frontseat2011.aspx

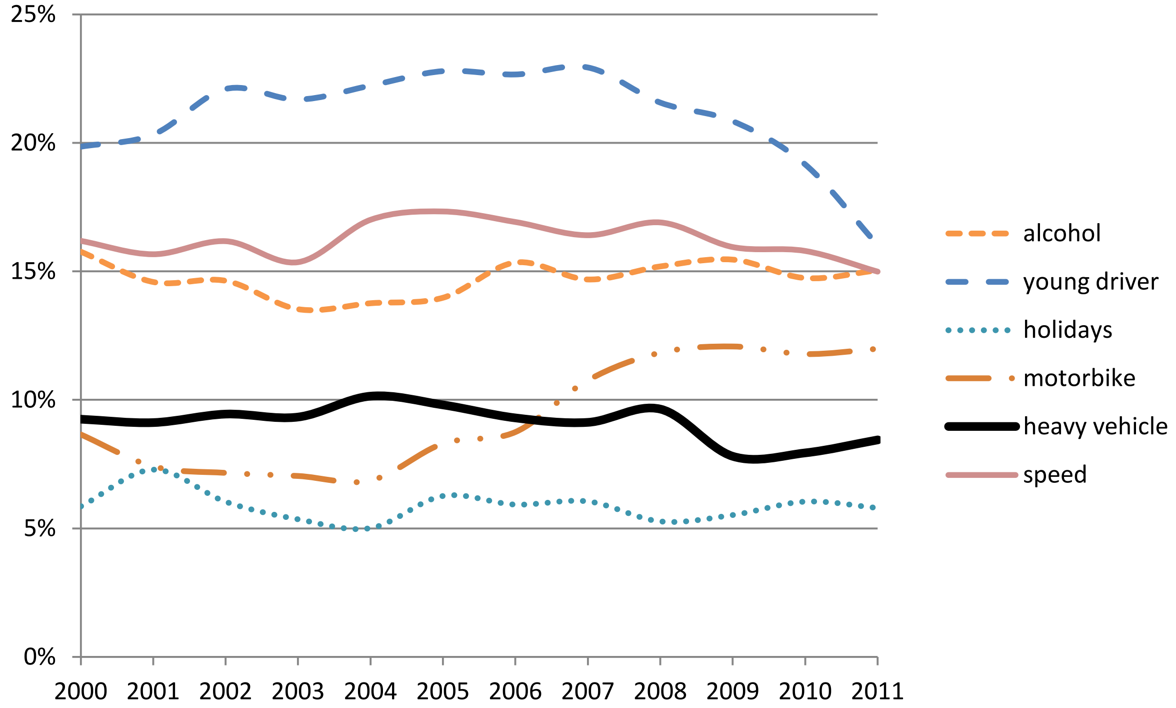
Figure 8: Unemployment rates



Patterns in injury and fatal crashes

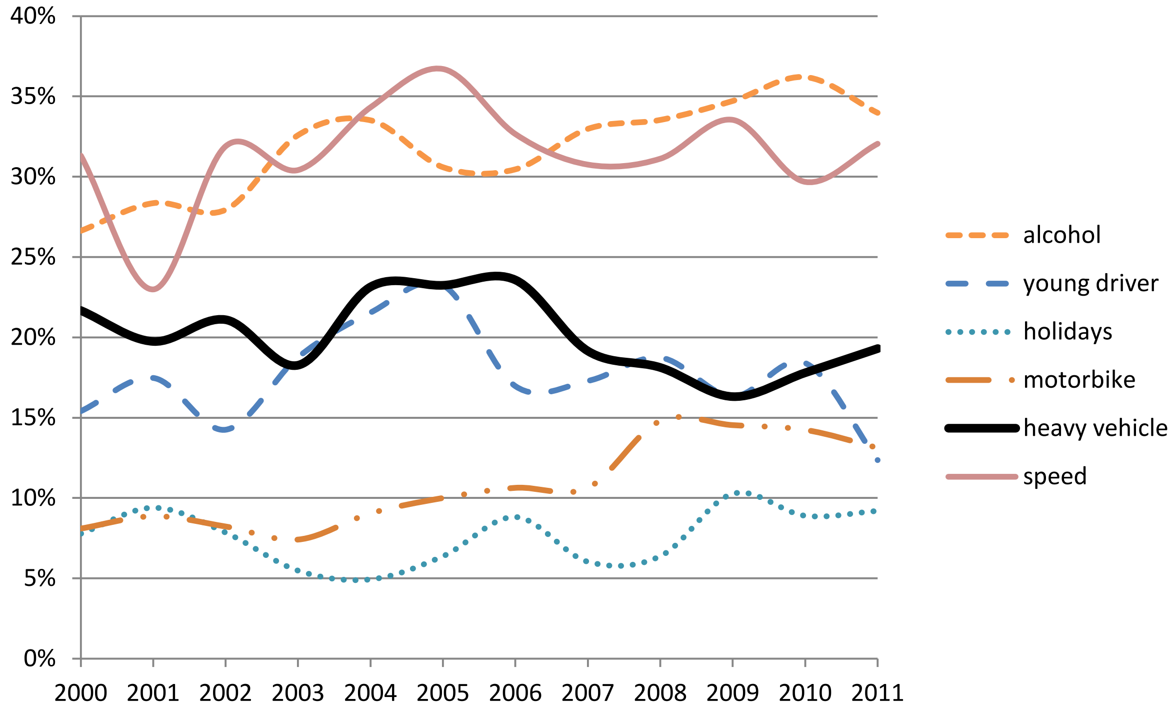
Figure 9 and Figure 10 provide an indication how individual factors might be influencing road injury trends over the past decade. The patterns for all injury crashes (Figure 9) show a steep fall in crashes involving young drivers, consistent with changes in licensing policy and alcohol limits for this group, and also potentially with the effects of the recession, which may affect young people more than other age groups. Heavy vehicle crashes fell and crashes involving motorcycles/scooters have risen coincident with the recession and with petrol price rises. But the proportions of these latter crashes changed little between 2010 and 2011. Crashes involving alcohol and occurring on public holidays have been relatively constant proportionally over the decade. The proportion of speed-involved crashes appear to be trending downwards somewhat since around 2004-5.

Figure 9: Proportions of *injury* crashes by year that involved: alcohol; drivers aged under 20; public holidays; motorcycles or scooters; heavy vehicles; excessive speed



With the smaller numbers of fatal crashes, Figure 10 shows much more variation than for the injury crashes. Given this amount of variation, the patterns can be said to be generally consistent with Figure 9 and show no sudden changes from 2010 to 2011.

Figure 10: Proportions of *fatal* crashes by year that involved: alcohol; drivers aged under 20; public holidays; motorcycles or scooters; heavy vehicles; excessive speed.



New Zealand Household Travel Survey (NZHTS) analysis

Introduction to NZHTS analysis

We did not expect the NZHTS to deliver time series data suitable for inclusion in the econometric modelling. Rather we aim for it to contribute evidence about the plausibility of various changes in risk-related travel behaviour over time. For example, although the small decrease in traffic volume in 2011 (compared with 2010) is clearly insufficient to explain much of the reduction in fatalities, the NZHTS may be able to suggest changes in travel patterns (affecting the *composition* of traffic) that are associated with lower risk. We looked for evidence of longer-term trends in composition over the past few years, in addition to any evidence of changes specific to 2011.

More specifically, we used the NZHTS to explore:

- vehicle occupancy (e.g. is occupancy falling and hence reducing exposure of passengers despite kilometres driven remaining fairly constant?)
- travel purpose (e.g. are changes in travel purpose occurring that may reduce crash risk?)
- time of travel (e.g. is there a change in the balance of weekend versus weekday travel)
- travel behaviour by those aged under 25, a high-risk group.

For good statistical reasons, published output from the NZHTS normally combines responses from two years or more. However, in this case, we looked at trends for periods as short as six months, mainly because the only NZHTS available to us for 2011 was for the first six months. Given that one of our objectives was simply to check whether there was any evidence of possibly dramatic changes in travel behaviour in 2011, we believe this use is acceptable. Results below (when not concerning subgroups) are based on 4099 respondents for January through to June 2011 and a minimum of 1295 respondents for 6-month periods in earlier years.

Vehicle occupancy

The large reductions in deaths of passengers in 2011 (38% decrease compared with 17% for drivers) suggested that we should investigate possible changes specifically causing reductions in passenger deaths. A first possibility to check is that exposure might have decreased, with less passenger travel occurring for some reason, despite total vehicle kilometres travelled not dropping much in 2011.

There is no evidence from the NZHTS of a sharp decrease in vehicle occupancy in the first half of 2011. More specifically, average occupancy (per kilometre driven[9]) was 1.56 for the first six months of 2011 compared with 1.58 for the same six months in 2010 and 1.60 for 2009. Such small changes

[9] Consistent with previous analyses of occupancy in New Zealand (Sullivan & O'Fallon, 2010), occupancy rates presented here refer to mean occupancy per kilometre driven (or, more exactly, person-kilometres of travel per kilometre driven) rather than per trip leg. As discussed in those previous reports, reasons for presenting results per kilometre driven than per trip leg include: matching good practice shown in occupancy analyses done internationally; keeping estimates conceptually consistent with occupancy as commonly measured in New Zealand by roadside observation; and matching common-sense intuition that an appropriate average should be more influenced by longer trip legs than short ones.

are within the margins of error due to random sampling fluctuations.[10] However, looking back to the start of the survey in 2003, occupancy is probably falling slowly. Mean occupancy was 1.66 for the first two years of the survey (July 2003 to June 2005) but 1.57 for two most recent years available (July 2009 to June 2011). Although small, this fall is probably statistically significant given the small margins of error for nationwide estimates of occupancy. Furthermore, a fall in occupancy is plausible given the continuing fall in household size in New Zealand[11] and the clear association between household size and vehicle occupancy (Sullivan & O'Fallon, 2010).

Travel purpose

Changes in travel purpose over time might suggest different types of trips are now occurring, with different risks. No clear change for 2011 was apparent in the NZHTS data concerning trip purpose. In particular, there was no obvious reduction in trip purposes that appear more discretionary and hence potentially more liable to reduction during times of economic pressure or high fuel prices. The proportion of trips classified as 'Social visits' or 'Recreational' was 17.3% for the first six months of 2011, very similar to the 17.6% for the same months in 2010. Nor was the proportion of work related trips markedly different (15.6% for the first six months of 2011, and 15.9% for the same months in 2010). (These figures are weighted by the distance of each trip, in addition to the usual trip weights, for parallel reasons to those given for also analysing occupancy per kilometre driven.)

Assessment of whether or not a change in travel purpose had occurred was limited to examination of trends since mid-2009 because an extra trip purpose code (overnight lodging, accounting for around 4% of trips) was introduced into the NZHTS questionnaire at that time.

Time of travel

Relatedly, changes in travel purpose might be reflected in a different time of travel and that might in itself have a different level of risk. We assessed this at a broad level only, comparing weekend with weekday travel. Again, no marked difference was evident. Specifically, 23.0% of kilometres driven were during the weekend in the first six months of 2011 and this was similar to previous years (e.g. 23.3% in the first six months of 2010). Nor was any longer term trend visible since 2003 in this measure.

Travel of younger drivers

Younger drivers are an age-group with a particularly high risk per kilometre travelled (Ministry of Transport, 2011). Hence it is possible that a reduction in their driving could explain part of the reduction in the road toll without their reduction in driving being evident in the total traffic volume. Furthermore a reduction in their driving is plausible because of the effects of the recession. That is, high youth unemployment may have particularly reduced availability of cars for young people; also, the amount they drive may be particularly sensitive to high fuel prices. In addition, a reduction in driving by 15 year olds is likely in 2011 because of the increase to 16 as the minimum age for a learner licence in August 2011.

NZHTS figures suggest that a decrease in driving by younger drivers in the first half of 2011 may have occurred; but the results are not at all definitive because of the combined effects of (a) small sample

[10] Some illustrative margin of error calculations for vehicle occupancy are included in Sullivan & O'Fallon (2010, p49).

[11] www.stats.govt.nz/browse_for_stats/population/estimates_and_projections/demographic-trends-2010/chapter8.aspx

sizes for younger age groups (e.g. 274 respondents aged 15 to 19 during the first six months of 2011 who reported some driving), and (b) the sensitivity of estimates of kilometres driven to a small number of long trips. For example, the estimated distance driven by those aged 15–19 in the first six months of 2011 was roughly half the distance for the same six months in 2010 and 2009; on the other hand, it was similar to estimates for the first half of 2006, 2007, and 2008.

The NZHTS figures on driving are consistent with overseas findings of recent reductions in driving by younger drivers (IRTAD, 2012). Nevertheless, we must be realistic about how much younger drivers might contribute to the reduced road toll in 2011: there was a decrease of 11 (18%) in deaths of drivers aged 15–24 in 2011 compared with 2010. Considering all road deaths rather than just driver deaths (which allows us to narrow the age range considered to focus on those at greatest risk), the decrease of 17 (from 52 to 35) in road deaths for those aged 15–19 was smaller in both absolute and percentage terms than the drop for those aged 25–39 (decrease of 30, from 76 to 46).[12] Note that over a 10-year time frame, the greatest age-related reduction in road deaths is for the 0–14 age-group: their road deaths fell by 52% between 1999–2001 (106 deaths) and 2009–2011 (51 deaths). This is likely to be largely related to reduced pedestrian and cyclist activity by this group. For children aged 5-14, the time spent walking and cycling averaged over 2 hours per week in 1997/1998 but only about one and a quarter hours per week in 2004-2007 (Ministry of Transport, 2008).

[12] Source: Ministry of Transport (Quarterly report 2011Q4 v1.xlsx, worksheet Age2)

Section 3: Time series analysis

Objective

Time series analysis looks at the way that road deaths change over time and whether other potentially causal factors measured over the same period appear to explain variation in the counts of road deaths. As noted previously, the objective is not to explain the longer term downward trend in road deaths. Rather it is to assess the degree to which the marked downward departure from the trend in 2011 can be attributed to any particular causes, rather than to random variation.

Overview of analysis

We adopted a two stage estimation approach: a long-term model to capture the downward trend in fatalities by a linear trend variable and an allowance for seasonality; a short-term model to explain the remaining variation according to changes in various independent variables. These included various economic variables, road safety enforcement and advertising, traffic volumes and alcohol consumption. There was a drop of 91 road deaths from 2010 to 2011. Petrol prices, wage levels and motorcycle registrations together explained 21 of these deaths, the long-run trend explained 20 deaths and 50 deaths were not explained by the models.

Framework

In designing a model it is perhaps useful to distinguish between factors that influence the probability of an accident, and those that affect the probability of death, given that an accident occurs.

Factor	Pr (accident)	Pr (death |accident)	Comment
Road engineering	x	x	Long run (LR) trend
Amount of travel	x		}Social & economic
Type of travel	x	x	}determinants
Speed	x	x	Education, advertising & enforcement
Weather	x	x	Exogenous
Primary vehicle safety features (stability control etc.)	x	x	Vehicle stock – LR trend & short run variation
Vehicle crashworthiness ratings		x	Vehicle stock – LR trend & short run variation
Road user behaviour	x	x	Education & regulations, use of child restraints, graduated licences – LR trend
Alcohol consumption	x		Education, advertising & enforcement, some LR trend

Because so many variables affect both probabilities, the gain from developing a two-stage model is probably small. Hence a model for road deaths needs to consider the following underlying causative factors:

1. Long run trend (for gradual changes in the nature of the vehicle stock, road quality, medical care and driver behaviour – affected by education, enforcement etc.)
2. Economic factors or that determine the amount of travel, or more directly a travel volume indicator

3. Short-term changes in vehicle quality
4. Advertising – short-term effects
5. Enforcement – short-term effects
6. Weather.

Note that the advertising and enforcement measures need to be input measures, not output measures. For example we could include the number of compulsory breath tests carried out, but not the number of people caught over the breath or blood alcohol limit. The problem here is ambiguity of the sign of the coefficients in the regression. That is, an increase in the number of drivers caught over the limit could be attributable to more enforcement (such as compulsory breath tests), in which case we expect a negative correlation with road deaths; or to more people on the road who drink and drive, in which case we expect a positive correlation with road deaths. If the two effects are approximately equal the model would generate a statistically insignificant zero effect. A non-zero effect is difficult to interpret.

To the extent that drink-drive messages take a long time to influence driver behaviour and proficiency, their effect may be similar to the gradual penetration of traction control in the vehicle fleet, and difficult to statistically isolate from the effect of improved driver education across a range of domains. In any case that is not part of our task.

Model structure

Given that we are interested in the unusual drop in 2011, we adopt a two stage estimation approach:

1. Long-term model: Capture the downward trend in fatalities by a linear trend variable and an allowance for seasonality. (Recall that we are not attempting to explain the long-term trend).

2. Short-term model: Endeavour to explain the residuals in Model 1 (i.e., the variation in the series not accounted for by Model 1) by changes in various independent variables.

Because the residuals of Model 1 are stationary, the two-stage approach takes care of the non-stationary nature of the road toll series – a characteristic of the data that has confounded much previous analysis of the road toll. Many of the independent variables are also non-stationary[13] and therefore need to be differenced (only once) before being used in Model 2.

Algebraically the two models are as follows:

Model 1: $$y_t = \alpha_0 + \sum_{i=1}^{3} \alpha_i ZSEAS_{it} + \alpha_4 T_t + \epsilon_t$$

Model 2: $$\varepsilon_t = \beta_0 + \sum_{i=1}^{n} \beta_i \Delta X_{it} + \mu_t$$

[13] Testing for stationarity is done using the methodology of Dolado et al (1990).

The model estimation period extends to the December quarter of 2010, so there is no possibility of the 2011 data affecting the estimated parameters. We then run the model using actual 2011 values for the explanatory variables and 'predict' the quarterly road toll in 2011. Comparison of these predicted values with the actual values then provides us with an estimate of the degree to which the 2011 drop in the road toll can be attributed to particular causes versus random variation.

Unfortunately this methodology is not guaranteed to produce the desired result. The main problem is that there could be some non-random characteristics that uniquely affected the road toll in 2011, which by definition cannot be captured in an econometric analysis of a period that ends in 2010. The effects of such characteristics would only be able to be investigated some years after 2011.

Model 1

Only one seasonal term was required to remove seasonality.

Results (Model 1)

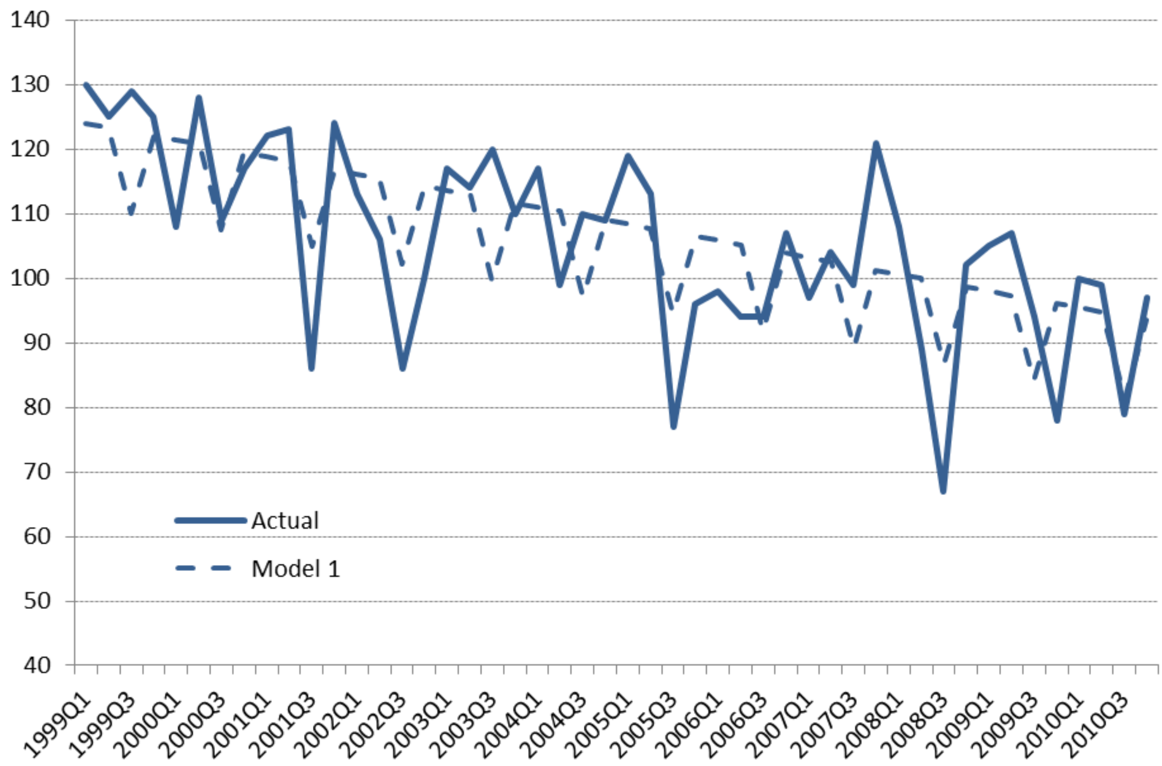
R^2 = 52.5%.
Mean absolute quarterly error: 8.2 deaths.
Standard error: 10.4 deaths.
DW test: p-values of 0.21/0.79 for positive/negative autocorrelation.
JB normality test for residuals: p-value: 0.61.

Table 3: Model 1

	Coefficient	p-value	Comment
Trend	-2.597	0.000	Ongoing 10.4 fewer deaths/year
September	-12.65	0.001	

As shown in Figure 11, the model's main weaknesses are its overstatement of the road toll in 2002 and 2005/06, and its understatement in 2007.

Figure 11: Model 1 Actual v estimated



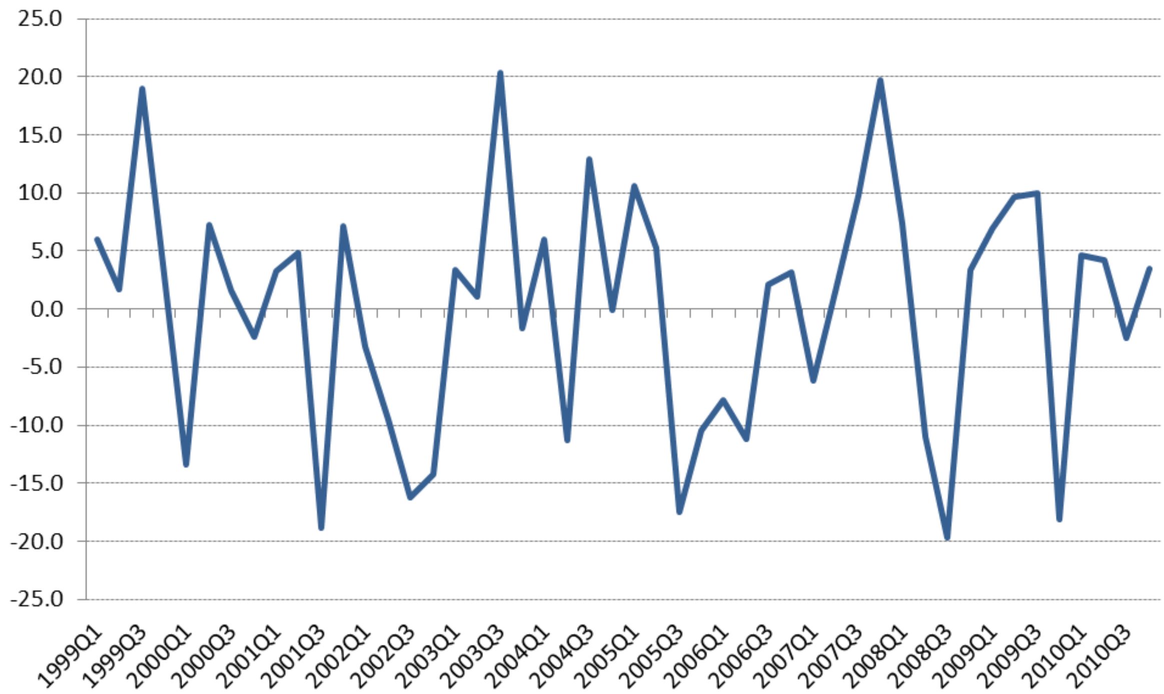
Projecting the estimated series through to 2011 results in predicted road deaths of 355 compared to an actual figure of 284, a difference of 71, which reflects four successive quarters of overstatement by the model for 2011 of 22.8, 23.2, 11.9 and 12.9 respectively. Thus the first two quarters in particular are well outside the model's mean absolute error.

For 2010, Model 1 predicts 365 fatalities, compared to an actual of 375. Thus 22% (20 fatalities) of the large drop in fatalities (91) between 2010 and 2011 can be seen as a return to the long-term trend. These 20 fatalities are the difference in 2010 between Model 1 and actual fatalities (10), as well as the long run trend of 10.4 fewer deaths per year.

Model 2

As shown in Figure 12, the second stage model is quite a tough specification as there appears to be a considerable amount of random noise in the residuals from Model 1.

Figure 12: Model 1 residuals



Variables examined

In Model 2 there are some broad groups of variables that should be examined (see Table 4). For both advertising and enforcement we are looking for short-term effects in Model 2 rather than the effects of long-term exposure to these variables, which is hopefully picked up in the trend variable in Model 1.

Table 4: Model 2 variable groups

Variable group	Comment
Travel	Either directly measured by, say, the state highway travel volume index or the odometer based travel volume index, or by changes in one of more of the economic determinants of travel, including fuel prices, real GDP, etc.
Advertising	Target Audience Rating Points (TARPs) or advertising recall measures.
Enforcement	Number of compulsory breath tests (CBT) and/or mobile breath tests (MBT).
Short-term changes in vehicle quality	Either a direct measure or a variable that captures the underlying ability of firms and households to purchase better vehicle quality – not just newer vehicles but also better tyres, less overloading and so on. Many economic determinants such as GDP would also affect the demand for travel and thus have the opposite sign to what would be their expected effect on the road toll via changes in vehicle quality. To reduce this risk we use labour productivity, proxied by the real product wage rate (deflating wage rates by the GDP deflator, not the CPI).
Weather	Weather is tricky variable to include in the analysis of fatalities. First, its effect on fatalities is not clear from theory alone. Bad weather could increase the risk of an accident or fatality simply because vehicle control is more difficult, but the relationship might be negative if bad weather deters people from driving or causes them to drive more carefully. If speeds are slower the probability of death, given an accident, might be lower in bad weather. Second, data is an issue. Quarterly average rainfall (and fog and snow) figures or the number of 'rainy days' in a quarter are far too crude to convey useful information about the relationship between accidents and bad weather. The only useful data we have on weather is what the weather conditions were where and when a fatality occurred. We do not know how many instances of bad weather there were (and where) that did *not* coincide with a change in fatalities. Unfortunately we cannot use bad weather fatalities (or some transformation thereof) to predict total fatalities.

Table 5 below shows the results. The following variables in differenced form were also examined in Model 2, but have no statistical significance.

- Real GDP (growth rates as well as differences)
- Terms of trade (possibly affecting rural travel)
- Real price index for light vehicles
- CBT and MBT
- Advertising
- Interest rates (mortgage, not differenced)
- State Highway travel volume index
- Alcohol per person aged 15 and above, available for consumption
- Dummy variable for Waitangi day or ANZAC day falling on a weekend or other public holiday
- Dummy variable for Waitangi day or ANZAC day creating a long weekend.

In addition, visual inspection suggests that the following are also most unlikely to provide any explanatory power:

- Unemployment (deteriorates well before 2011)
- Real private consumption (growth falls well before 2011, similar to GDP)
- Speed (free travel speeds) – also no quarterly series available.

Results (Model 2)

R^2 = 37%.
Mean absolute quarterly error: 6.4 deaths (about 6.2%).
Standard error: 8.4 deaths.
DW test: p-values of 0.25/0.75 for positive/negative autocorrelation.
JB normality test for residuals: p-value: 0.80.

Table 5: Model 2

	Coefficient	p-value	Std Dev	SD of level
Δ4 Real petrol price index	-0.149	0.024	20.3	23.9
Δ1 Real product wage	-25.45	0.000	$0.21/hr	$0.71/hr
Δ1 Motor bike registrations[14]	0.00075	0.092	3005	17726

An increase of one standard deviation (20.3 cents) in the differenced real petrol price is associated with about 3.0 fewer road deaths per quarter. As the real product wage is expressed in dollars per hour, a change of $1 has an effect of 25.5 deaths. So an increase in the real wage rate of 10c/hr is associated with a reduction of 2.5 deaths. The significance of this variable is interesting as it implies that the road toll is affected by short-term changes per capita wealth, over and above the ability of an economy to finance the longer term downward trend in the road toll through better roads, improved emergency health care, more education and so on.

Motorcycles registered have an effect of 2.3 deaths for a one standard deviation change (3005 increase or decrease in the number of registrations) in the differenced series (turning the stock into a flow), but the series is only just statistically significant at the 10% level, although a one-tailed test is arguably more sensible. Its p-value improves to 0.063 if the real petrol price is differenced over consecutive quarters rather than differenced over the same quarter of the previous year, but the p-value for the real petrol price then deteriorates to 0.111 and the overall R^2 declines to 32%. This suggests some correlation between these two variables, presumably caused by higher petrol prices encouraging a switch to motorcycles.

It seems fairly obvious that fewer motorcycle deaths have been a major contributor to the longer term overall downward trend in the road toll (that is from a peak of over 140 motorcycle deaths annually in the late 1980s to around one third of that total in recent years), but this does not

[14] Motorcycles are combined with mopeds. Although conceptually it might be better to exclude mopeds (given the comparatively small number of moped fatalities), limited data before 2000 makes the calculation of a series that excludes mopeds less reliable. Thus we have opted for the combined series. We did test the model with an estimated series that excluded mopeds, but this produced no improvement in the model.

automatically mean that the quarterly change in motor cycle deaths help to explain volatility around the trend.

In Table 6 the error from Model 1 (that is the departure from trend) is compared with the proportion of total fatalities accounted for by motor cyclist deaths. While the proportion was lower in 2011 than in 2009 and 2010, years when the road toll was above trend, in 2008 the proportion was unusually high when the road toll was well below trend. The reverse situation occurred in 2007.

Table 6: Motorcycle fatalities and model error

	Model 1 Error	MB deaths %
2006	-13.7	9.9
2007	24.7	9.5
2008	-19.9	14.1
2009	8.5	12.5
2010	9.9	13.4
2011	-70.8	11.6

Yet, as Model 2 shows, changes in motorcycle registrations do have some explanatory power at the quarterly level, confirming the ability of econometrics to isolate the possible confounding effects of other factors. Nevertheless we should also concede that changes in motorcycle registrations could be picking up the influence of other factors that are positively correlated with both motorcycle registrations (which are presumably correlated with use) and road fatalities. Accordingly one has to be careful about how the presence of this variable is interpreted, let alone any policy consequences.

More generally, the coefficients on any of the variables in Model 2 could be biased if they are correlated with omitted variables. For example motorcycle registrations might be correlated with advertising that highlights the risk of bike fatalities.

Projecting the estimated series through to 2011 accounts for 21 further fatalities, reducing the Model 1 error (fatalities not accounted for by Model 1) of 71 to 50, composed of four quarterly errors of -19.6, -15.5, -8.8 and -6.3 for March, June, September and December 2011 respectively. The standard error of the model is 8.42, so a 95% confidence interval is ±17.0,[15] implying that only the March quarter of 2011 is an outlier, but of course the unusual feature of 2011 is that for four successive quarters the sign of the error is the same. See Figure 13.

If road fatalities follow a Poisson distribution,[16] the variance is equal to the mean. The latter is 105.7 (1999-2010), so the standard deviation is 10.3, which is greater than the size of the standard error of 8.4 in Model 2, and therefore consistent with no overdispersion (caused by the mean itself being random). Indeed there is a risk of over-fitting, probably caused by the interaction between petrol prices and motorcycle registrations discussed above. This may compromise the predictive power of the model.

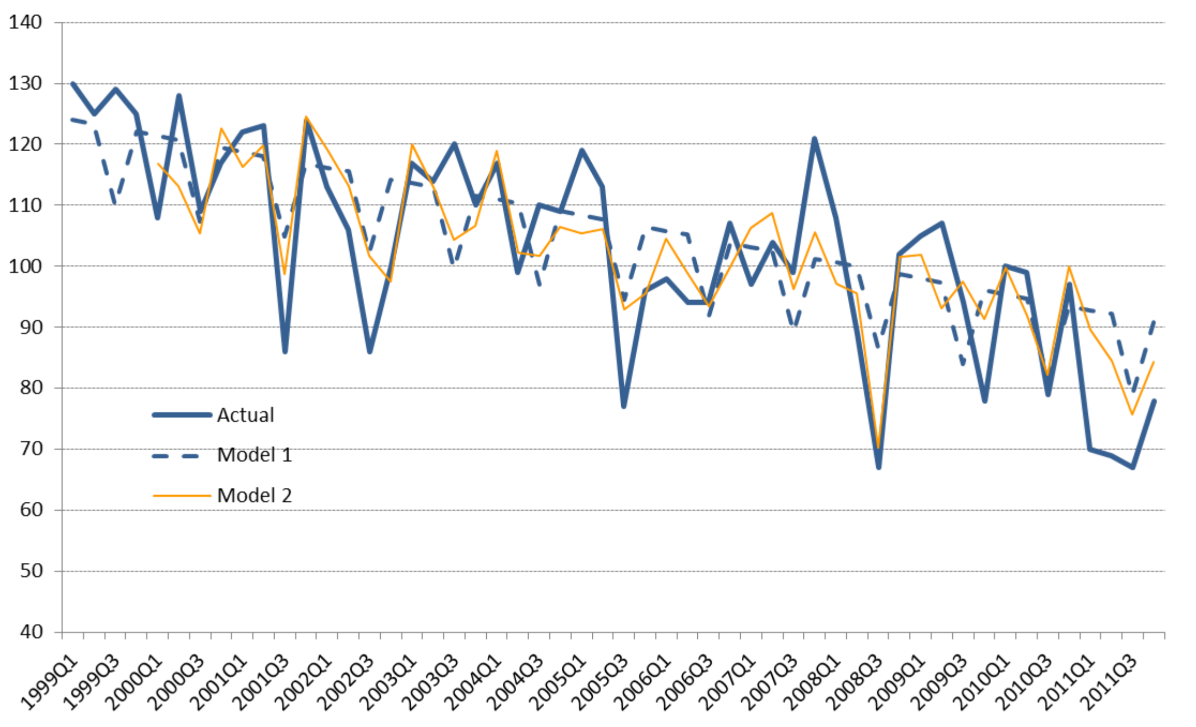
A 95% Poisson confidence interval for quarterly fatalities based on a mean of 105.7 ranges from 86.8 to 127.1. Excluding the effect of the downward trend, the March and June quarters of 2011 are outside this interval. In other words there were two successive quarters where the probability of the

[15] This has a t-distribution with 40 degrees of freedom.

[16] Fridstrøm et al. (1995). Note that strictly speaking it is number of fatal accidents that follows a Poisson distribution, not the number of fatalities, which would follow an overdispersed Poisson distribution.

observed event occurring was less than one in twenty. This has the effect of making the outcome for the year as a whole lie outside the lower bound of a 95% confidence interval. This also happened in 2002. There were no calendar years (in the sample from 1999 through 2011) where the annual toll was above the upper bound of the 95% confidence interval, but the year ended March 2008 was close.

Figure 13: Models 1 & 2 Projected to 2011



At this stage it looks as if the 50 unexplained deaths are attributable to some combination of:

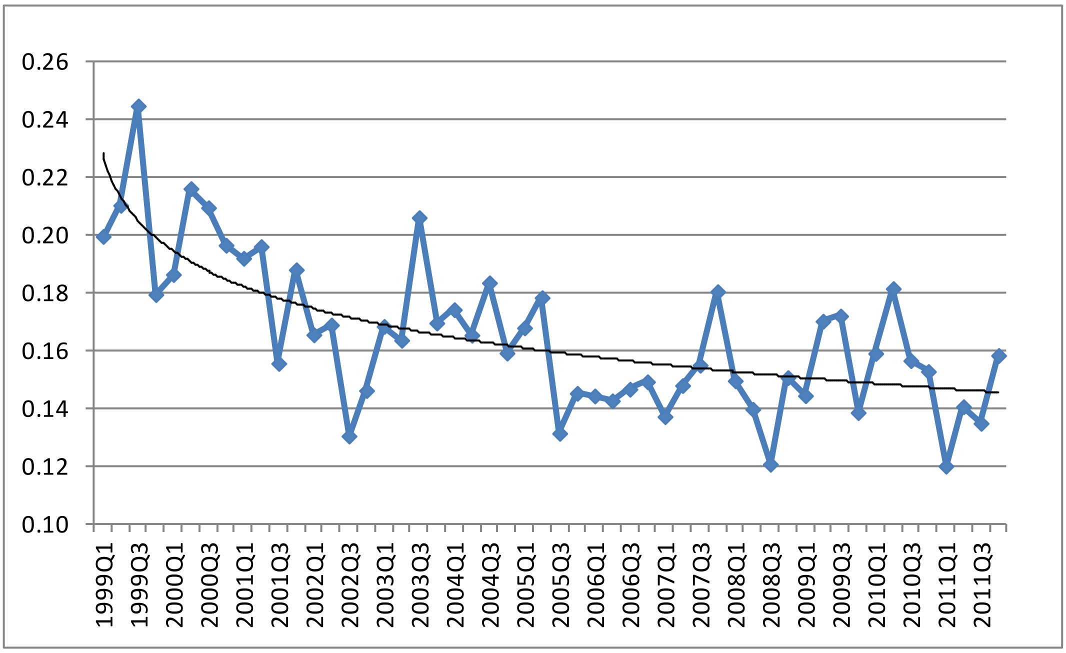
- Random variation
- Factors that we have not been able test, namely events or policy changes that are unique to 2011, but with more observations could be examined.
- Unknown reasons.

In the following sections we look at other factors that might help explain the low road toll in 2011.

Serious casualties

Trends in serious (hospitalised) casualties may shed light on underlying factors that influence the road toll. Therefore, it is worth looking at whether 2011 was characterised by a marked change in the ratio of fatalities to serious casualties. Serious casualties are those considered by the Police officer attending the crash to be severe enough to require admission to hospital. The ratio is shown in Figure 14. A logarithmic trend fits the data quite well. Clearly there is a story behind the declining trend, but that is beyond the scope of this report. Our interest is in departures from the trend, which may point to changes in factors that influence survivability in the event of a crash beyond those driving the trend, or to changes in factors that are more typical of fatal than non-fatal crashes, such as high levels of alcohol and drugs (in themselves decreasing survival rates for physiological reasons) and higher speed crashes.

Figure 14: Ratio of fatalities to serious casualties



The standard deviation of the error term (the difference between the actual ratio and the ratio implied by the curve, up to 2010) is 0.0200. In comparison the error for the four quarters of 2011 are -0.0262, -0.0052, -0.0106 and +0.0133 respectively. Thus 2011 does not seem particularly unusual.

Overall for 2011 the average expected ratio is 0.1458, compared to an observed 0.1387, a difference of about 5%, which is much smaller than the 20% difference between actual fatalities and the number expected from Model 1.

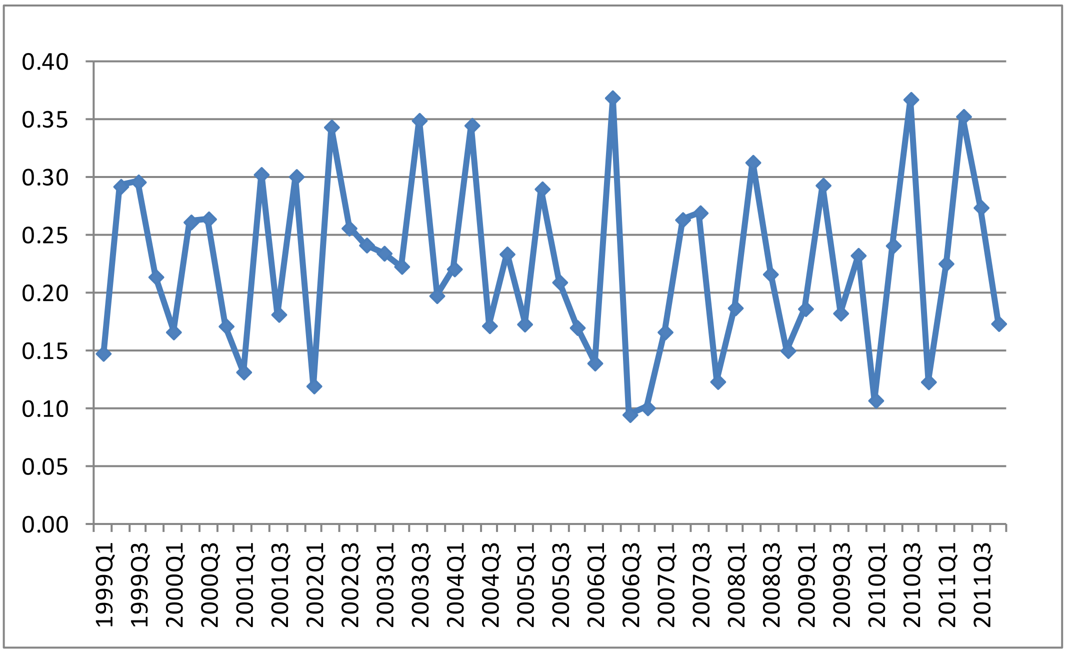
This result is consistent with the large decline in fatalities in 2011 having a considerable component of random variation. However, it is also consistent with some unknown events or behavioural changes in 2011 that affected fatalities, but had almost no effect on serious casualties. From the data available now (mid-2012) no such event or behavioural shift is identifiable.

Weather

Perhaps 2011 had unusual weather. As discussed above (page 30), the data we have on weather is not ideal for the purpose of econometrically investigating its effect on fatalities.

Figure 15 shows the proportion of fatalities where adverse weather (rain, mist or snow) was cited as a contributing factor. There is no trend around a mean of 22.5% and a standard deviation of 7.5%, with the last two years exhibiting quite marked quarterly volatility. Smoother annualised deviations from trend for the last six years are shown in Table 7.

Figure 15: Share of fatalities with bad weather as contributing factor



While the proportion of fatalities affected by adverse weather was relatively high in 2011, there does not appear to be a consistent relationship between the departure from trend in fatalities (that is the Model 1 error) and the departure from the mean proportion of adverse weather fatalities.

The picture in 2011 means that the ratio of adverse weather affected fatalities to total fatalities increased, at the same time as the total number of fatalities decreased. This implies that the reduction in fatalities was dominated by fewer fatalities in good weather. So we can infer that the low road toll in 2011 is consistent with better weather, but we do not really know if the weather was truly better in 2011 (and that good weather is associated with fewer fatalities) or if there were fewer accidents in good weather for other reasons, including random chance. Indeed given the volatility that is apparent in Figure 15, random chance must be the favoured explanation.

Table 7: Adverse weather fatalities and model error

	Model 1 Error	% Adverse weather actual – Mean
2006	-13.7	-4.8%
2007	24.7	-1.9%
2008	-19.9	-0.8%
2009	8.5	-0.1%
2010	9.9	-1.5%
2011	-70.8	3.2%

Figure 16 reinforces the above analysis. Although there was a lower proportion of fatal crashes in fine weather in 2011 (a similar proportion to 2003), for all crash severities the proportion in fine weather was about average, indicating that the weather (as an environment for driving) was not unusual in 2011.

Figure 16: Percent of fatal crashes and all crashes in fine weather by year

Conclusions

The changes in particular casualty types found in the analyses of road deaths from countries with much larger populations than New Zealand are important in showing the potential effects of economic factors. However similar analytical approaches cannot be used for the New Zealand data as the numbers within given casualty classes tend to be too small to show reliable trends.

An advantage for the New Zealand analysis is the availability of a large number of data sources (on travel, on-road speeds, alcohol use by drivers, licensing data, etc.) that can help identify underlying factors. Our analysis of these data sources showed a generally improving road safety environment over the past decade without any apparent major changes from 2010 to 2011.

The second stage of the analysis (see Section 3) was to fit econometric models to seek to understand the way that road deaths have changed over time and whether potentially causal factors measured over the same period appear to explain variation in the counts of road deaths. The objective was not to explain the longer term downward trend in road deaths. Rather it was to assess the degree to which the marked downward departure from the trend in 2011 can be attributed to any particular causes, rather than to random variation.

Statistically significant factors that were found to be associated with the variation in road fatalities over the past decade (apart from the long run trend) included: changes in the real petrol price index; changes in real product wages; changes in motorcycle registrations. This analysis also indicates that much of the large decline in fatalities in 2011 is consistent with the sort of random variation expected for these sorts of series. However, it is also consistent with some unknown events or behavioural changes in 2011 that cannot yet be empirically examined.

References

Cheung I, McCartt AT (2011) Declines in fatal crashes of older drivers: Changes in crash risk and survivability, Accident Analysis & Prevention 43:pp. 666-674.

de Place E, Rood T (2011) More Money, More Cars. Sightline Daily.

Dolado JJ, Jenkinson T, Sosvilla-Rivero S (1990) Cointegration and unit roots, Journal of Economic Surveys 4:pp. 249-273.

Elvik R (2010) The stability of long-term trends in the number of traffic fatalities in a sample of highly motorised countries, Accident Analysis and Prevention 42:pp. 245-260.

European Road Safety Observatory (2007) WP 7 – Data Analysis and Synthesis, SafetyNet, Vol 2012. Co-financed by the European Commision: Directorate-General Transport & Energy.

Fridstrøm L, Ifver J, Ingebrigtsen S, Kulmala R, Thomsen LK (1995) Measuring the contribution of randomness, exposure, weather, and daylight to the variation in road accident counts, Accident Analysis & Prevention 27:pp. 1-20.

Hagiwara T, Imoto T, Kagaya S, Takemoto A, Hirasawa M (2010) Estimation of Various Factors on Number of Fatal and Injured Accidents in Japan using in Past 25 years, Journal of Eastern Asia Society for Transportation Studies 8:pp. 1974-1985.

IRTAD (2012) Road safety annual report 2011. International Traffic Safety Data and Analysis Group.

Joksch HC (1984) The relation between motor vehicle accident deaths and economic activity, Accid Anal Prev 16:pp. 207.

Keall MD, Frith WJ (2004) Older driver crash rates in relation to type and quantity of travel, Traffic Injury Prevention, 5:pp. 26-36.

Kentikelenis A, Karanikolos M, Papanicolas I, Basu S, McKee M, Stuckler D (2011) Health effects of financial crisis: omens of a Greek tragedy, The Lancet 378:pp. 1457-1458.

Kim T, Rivara FP, Mozingo DW, Lottenberg L, Harris ZB, Casella G, Liu H, Moldawer LL, Efron PA, Ang DN (2012) A regionalised strategy for improving motor vehicle-related highway driver deaths using a weighted averages method, Injury Prevention 18:pp. 16-21.

Kopits E, Cropper M (2008) Why have traffic fatalities declined in industrialised countries? Implications for pedestrians and vehicle occupants, Journal of Transport Economics and Policy 42:pp. 129-154.

Law TH, Noland RB, Evans AW (2011) The sources of the Kuznets relationship between road fatalities and economic growth, Journal of Transport Geography 19:pp. 355-365.

Litman T, Fitzroy S (2010) Safe Travels; Evaluating mobility management traffic safety impacts. Victoria Transport Policy Institute and Fitzroy and Associates.

Longthorne A, Subramanian R, Chen CL (2010) An Analysis of the Significant Decline in Motor Vehicle Traffic Crashes in 2008. NHTSA, DOT HS 811 346.

Males MA (2009) Poverty as a determinant of young drivers' fatal crash risks, Journal of Safety Research 40:pp. 443-448.

Martensen H, Dupont E, Stipdonk HL (2008) Deliverable D7.11, The CARE data in perspective:Overview and Executive Summary of Work Package 7. In Martensen H, Dupont E (eds), SafetyNet. Vehicle Safety Research Centre.

Ministry of Infrastructure and Transport (2012) Australian Road Deaths Continue to Fall, Canberra

Ministry of Transport (2008) Walking for transport: Ongoing New Zealand Household Travel Survey 2003 – 2007, Wellington, New Zealand.

Ministry of Transport. (2010a). New Zealand Household Travel Survey. Retrieved August 19, 2010, from http://www.transport.govt.nz/research/travelsurvey/

Ministry of Transport. (2010b). Rates of driving under the influence of alcohol: Results of random CBT operation 1997 to 2010. Wellington: Ministry of Transport.

Ministry of Transport. (2011). Young drivers crash facts 2011. Wellington: Ministry of Transport. Retrieved from http://www.transport.govt.nz/research/Pages/YoungDriversCrashFacts.aspx

Ministry of Transport. (2012). Quarterly road toll report. Wellington: Ministry of Transport.

Page Y (2001) A statistical model to compare road mortality in OECD countries, Accident Analysis and Prevention 33:pp. 371-385.

Partyka SC (1984) Simple models of fatality trends using employment and population data, Accid Anal Prev. 16:pp. 211.

Partyka SC (1991) Simple models of fatality trends revisited 7 years later, Accid Anal Prev. 23:pp. 423.

Prato CG, Gitelman V, Bekhor S (2011) Pattern Recognition and Classification of Fatal Traffic Accidents in Israel: A Neural Network Approach, Journal of Transportation Safety & Security 3:pp. 304-323.

Rakauskas ME, Ward NJ, Gerberich SG (2009) Identification of differences between rural and urban safety cultures, Accident Analysis & Prevention 41:pp. 931-937.

Sivak M (2008) Is the U.S. on the Path to the Lowest Motor Vehicle Fatalities in Decades?

Sivak M (2009) Mechanisms involved in the recent large reductions in US road fatalities, Injury Prevention 15:pp. 205-206.

Sivak M, Schoettle B (2010) Toward Understanding the Recent Large Reductions in U.S. Road Fatalities, Traffic Injury Prevention 11:pp. 561-566.

Sivak M, Schoettle B (2011) Recent major improvements in road safety in the US: Changes in the frequency of crashes or the severity of the outcome of crashes.

Sullivan, C., & O'Fallon, C. (2010). Kilometres travelled and vehicle occupancy in urban areas: improving evaluation and monitoring (No. 399). NZ Transport Agency research report. Wellington: NZ Transport Agency.

Sze N-n (2008) Quantitative analyses for the evaluation of traffic safety and operations, Civil Engineering, Doctor of Philosophy. University of Hong Kong Hong Kong pp. 200.

Wagenaar AC (1984) Effects of macroeconomic conditions on the incidence of motor vehicle accidents., Accid Anal Prev. 16:pp. 191.

Weijermars W, Bijleveld FD, Stipdonk HL (2010) Further analysis of the decrease in the number of road fatalities in 2004 (De daling van het aantal verkeersdoden in 2004 nader geanalyseerd), Leidschendam 2262 AR Netherlands.

Appendix

Data sources

Our main sources are the core data on road safety supplied by the Ministry of Transport. If no source is explicitly listed for data in this report, then one of these sources was being used:

- Data on fatalities and injury crashes from the Crash Analysis System (CAS), which contains data on all traffic crashes reported by Police[17]
- Relatedly, a Ministry spreadsheet containing many summaries from the CAS and other major safety-related data (*Quarterly report 2011Q4 v1.xlsx*, supplied 9 March 2012).

The Ministry also supplied New Zealand Household Travel Survey (NZHTS) datasets for our analysis. The NZHTS aims to improve understanding of how and where people travel by recording every journey taken by an individual in a two-day period, the travel mode used, the distance travelled, and the purpose of the journey (Ministry of Transport, 2010a). Among other purposes, this enables estimation of crash risk for different groups of road users. The Ministry of Transport established the NZHTS as a continuous survey in 2003. Between July 2003 and June 2008, people in over 2,000 households throughout New Zealand were sampled each year. The sample size increased to around 4,600 households per year from July 2008. Further details about the method and a copy of the questionnaire are available on the Ministry of Transport website.[18]

Table 8 lists other data sources used.

[17] www.nzta.govt.nz/resources/crash-analysis-system/index.html
[18] www.transport.govt.nz/research/travelsurvey/

Table 8: Other data sources used

Data	Source
Land transport data	
Breath test numbers	NZ Police
Motor bike registrations	Ministry of Transport (derived from NZ Transport Agency vehicle registration data)
Road safety advertising measures	NZ Transport Agency
Speed (free travel speeds)	Ministry of Transport (Speed survey)
State Highway travel volume index	NZ Transport Agency
Economic	
Alcohol per person aged 15 and above, available for consumption	Statistics New Zealand
Interest rates (mortgage)	Reserve Bank of New Zealand
Real GDP	Statistics New Zealand
Real petrol price index	Ministry of Economic Development *New Zealand Energy Data File*
Real price index for light vehicles	Infometrics, from Statistics New Zealand data
Real private consumption	Statistics New Zealand
Real product wage	Infometrics, from Statistics New Zealand data
Terms of trade	Statistics New Zealand
Unemployment	Statistics New Zealand

Recommendations for follow-up research

Model 1 shows that the decline in road fatalities over the last decade or so is well approximated by a linear trend, but that tells us little about the relative contribution of the factors that have contributed to the trend.

Previous studies have demonstrated that it is not an easy task to isolate the separate effects of variables such as better vehicles, better roads and better driver behaviour. Data is frequently poor, and many of these variables themselves exhibit strong underlying trends, reflecting for example the time it takes for improvements in vehicle safety to percolate through the vehicle fleet, and the slow pace of influence that drink-drive messages have on public perception and thus on driver behaviour.

The trending nature (non-stationarity) of these series has the potential to produce spurious findings about the measured effects of the various explanations. Even with the best econometrics though, it may be impossible to isolate separate effects where two or more variables are strongly interactive. For example a hard-hitting advertising campaign about the dangers of drinking and driving combined with more visible enforcement may be far more effective than the sum of two initiatives when implemented at different times.

It has been demonstrated above that at this stage we cannot identify any major factors that are strong enough to explain most of the unusual reduction in the road toll in 2011, leading us to suspect that it is largely a statistical aberration. From a policy perspective, however, the long-term trend is far more relevant, so the sharp decline in 2011 will become more significant if it eventually turns out to be the start of a longer term shift in the trend. Identifying whether this is the case, and why, depends on developing a robust model that explains the trend to date.

This would also allow – indeed require – a more sophisticated approach to:

- Handling interaction between variables, such as between petrol prices and motorcycle registrations.
- Incorporating variables of unclear theoretical sign, such as the number of speeding infringements.

Our recommendation therefore is that further insight into the reasons for the declining road toll depends on explicit modelling of the longer term trend.

Some further analysis of travel patterns and trends would also be justified to shed light on the impact of the economic recession and of changes in licensing policy for young drivers. Given the high risk associated with younger drivers and that the NZHTS figures on driving are consistent with overseas findings of recent reductions in driving by younger drivers (IRTAD, 2012), we recommend that the Ministry monitor changes in young driver behaviour. For example, the NZHTS may soon be able to clearly confirm a reduction in driving by younger drivers or changes in their vehicle occupancy.