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# RETROSPECTIVE AND PROJECTED FUTURE IMPACT OF CHARACTERISTICS OF THE NEW ZEALAND AND AUSTRALIAN VEHICLE FLEET ON PEDESTRIAN INJURY

by

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**Title and sub-title:**

Retrospective and Projected Future Impact of Characteristics of the New Zealand and Australian Vehicle Fleet on Pedestrian Injury


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**Abstract:**

The objective of this study was to measure changes in pedestrian fatal and serious injury rates associated with gradual changes in the New Zealand and Australian light passenger vehicle fleet, and to project potential future changes in pedestrian fatal and serious injury rates that might arise with different scenarios of fleet changes and of safety technology uptake. From 2003-2011, it was estimated that improvements in pedestrian injury severity ratings saved an aggregate at least 37 fatal and serious injuries in New Zealand and around 340 in Australia. If these improvements were to continue with expected trends, compared to 2003 the 2020 fleet will have safety characteristics that will save an estimated additional 28-32 fatal or serious pedestrian injuries per year in New Zealand and around 170 additional per year in Australia. Using the characteristics of the 2011 fleet as a basis, the safety effects of a technology assumed to prevent 10% of pedestrian injuries was modelled. In aggregate over a 20-year period from the introduction of this technology to all new vehicles, 3.8% of all pedestrian injuries were estimated to be prevented. The penetration of emerging safety technologies into the New Zealand fleet is impeded by the current dominance of used imported vehicles from Japan. Some analysis was carried out of the expense justified by an emerging technology to prevent pedestrian injury. A technology that prevented 100% of pedestrian injury would justify an additional $914 per vehicle spent per vehicle to fit this technology. A technology that prevented only 10% of pedestrian injury, more realistic of typical technology effectiveness, would only justify an additional $91 per vehicle. This is likely to be insufficient to cover the expense of technologies such as the pop-up bonnet or hood, and pedestrian airbags, aimed specifically at preventing or reducing the severity of pedestrian injury. Nevertheless, many technologies, notably Brake Assist Systems, Intelligent Speed Adaptation and Collision Warning Systems have the potential to increase safety for all road users, including pedestrians. The likely wider applicability of the safety effects of these technologies increases the potential safety benefits, and also the acceptability to the motorist, who must pay for the additional costs of the technology when purchasing the vehicle.



**Key Words:**

Pedestrian injury
Fleet projection
Pedestrian safety technology





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# Preface

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**Contributorship Statement:**

Project Concept – SN, MK

Study Design – SN, MK, AD

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**Ethics Statement:**

Ethics approval was not required for this project.

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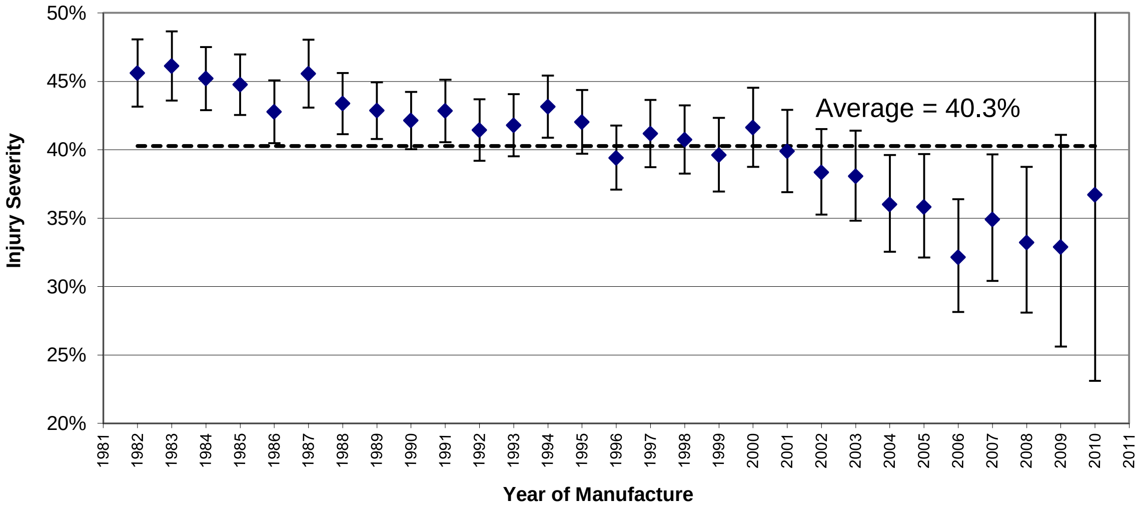
# EXECUTIVE SUMMARY

## *Objective*

The objective of this study was to measure changes in pedestrian fatal and serious injury rates associated with gradual changes in the New Zealand and Australian light passenger vehicle fleet composition, and to project potential future changes in pedestrian fatal and serious injury rates that might arise with different scenarios of fleet changes and of safety technology uptake.

## *Key Outcomes*

The average aggressivity (injury severity risk) of the Australasian vehicle fleet towards pedestrians has been improving over time with evidence of particular gains in recent years possibly reflecting the NCAP pedestrian testing regimes as well as the introduction of pedestrian protection regulations for vehicles in jurisdictions such as Europe and Japan.




The reduction in the fleet average injury severity risk for pedestrians was estimated to represent an annual fatal and serious injury saving of at least 14 in New Zealand and 75 in Australia for the 2011 fleet compared to the 2003 fleet. Over the period studied, from 2003-2011, it was estimated that these improvements in pedestrian injury severity ratings saved an aggregate at least 37 fatal and serious injuries in New Zealand and 340 in Australia. If these improvements continue with expected trends, compared to 2003 the 2020 fleet will have safety characteristics that will save an estimated 28-32 fatal or serious pedestrian injuries per year in New Zealand and 170 in Australia. These injury savings will be slightly lower if past trends in improving safety do not continue into the future.

Using the characteristics of the 2011 fleet as a basis, the safety effects of a technology assumed to prevent 10% of pedestrian injuries was modelled. After an 18-year period from the introduction of this technology to all new vehicles, 8% of all pedestrian injuries were estimated to be prevented in New Zealand per annum. The comparable figure in Australia was 6.1% saving per annum after 10 years reflecting the faster renewal of the Australian fleet. The penetration of emerging safety technologies into the New Zealand fleet is impeded by the current dominance of used imported vehicles from Japan.

Some analysis was carried out of the expense justified by an emerging technology to prevent pedestrian injury. A technology that prevented only 10% of pedestrian injury, realistic of typical technology effectiveness, would only justify an additional $91 per vehicle in New Zealand and $40 per vehicle in Australia. This is likely to be insuffient to cover the expense of technologies such as the pop-up bonnet or hood, and pedestrian airbags, aimed specifically at preventing or reducing the severity of pedestrian injury. Nevertheless, many technologies, notably Brake Assist Systems, Intelligent Speed Adaptation and Collision Warning Systems have the potential to increase safety for *all* road users, including pedestrians. The likely wider applicability of the safety effects of these technologies increases the potential safety benefits, and also the acceptability to the motorist, who must pay for the additional costs of the technology when purchasing the vehicle.

## *Implications*

Both Australia and New Zealand have benefited from reduced pedestrian road trauma through improvement in the pedestrian aggressivity of vehicle fleet. These benefits are predicted to continue for at least the medium term even if no further improvement pedestrian aggressivity of new vehicles occurs. It is likely that some of the improvements in vehicle pedestrian aggressivity have been accrued through the introduction of pedestrian protection performance requirements in jurisdictions such as Europe and Japan supported by the ANCAP pedestrian protection assessment. ANCAP should continue to be leveraged to encourage improvements in vehicle pedestrian protection performance whilst the adoption in Australia and New Zealand of mandated pedestrian protections standard already in place in other jurisdictions should be considered.

Due to the relatively low rates of pedestrian crashes in Australia and New Zealand, only small per vehicle investment in vehicle safety technologies to reduce pedestrian crash risk is possible for the investment to be cost effective. Encouraging the uptake of vehicle safety technologies that benefit both pedestrians as well as other road users is likely to be the most cost effective strategy as well as resulting in the greatest road trauma benefits. Encouraging through programs such as ANCAP competition between manufacturers to offer pedestrian protection technologies at minimal cost could also be an effective strategy.

Evaluation of new pedestrian crash avoidance technologies for vehicles is recommended as sufficient real world crash data become available. The effectiveness of broader crash avoidance technologies such as forward collision warning and ISA should be evaluated specifically for their effects on pedestrian crashes.

# 1 BACKGROUND

Pedestrian and cyclist injury is an important component of the Australasian road toll. In Australia, 224 pedestrians and cyclists were killed in 2011, constituting 17% of the road toll (BITRE, 2012); the corresponding figure for New Zealand in 2012 was 41, 13% of that year's road toll (NZ Transport Agency, 2013). Currently there are no Australasian vehicle safety regulations specifically aimed to minimise the risk of injury to unprotected road users, but the New Car Assessment Programs in Australia (from 2000), Europe (from 1997) and Japan (from 2003) all include pedestrian protection tests. Europe and Japan now have vehicle standards specified for pedestrian safety. As given makes and models are mass-produced for a variety of markets internationally, the establishment of these testing protocols and regulation standards will affect the safety characteristics of vehicles intended for the international market (Hu & Klinich, 2012). Analyses of pedestrian injuries have shown that the head and lower extremities are the most commonly injured body regions, which is the rationale for these regions to be the sole focus of the pedestrian impact-test procedures (ibid). Favourable test scores arise from front-end structures able to effectively absorb the energy of an impact with a pedestrian, focusing on these body regions. Active safety features (such as the pop-up bonnet or hood, and pedestrian airbags) have been the subject of no or limited evaluation.

Vehicle aggressivity ratings measure the injury risk that a vehicle poses to road users other than its own occupants (including other vehicle drivers, pedestrians, motorcyclists and bicyclists) in a collision. The Australasian Used Car Safety Ratings vehicle safety rating system includes a measure of relative vehicle aggressivity defined as the risk of death or serious injury to the other road user given crash involvement. Initially, two discrete indices were developed in the Australasian system separately considering other vehicle drivers and unprotected road users (pedestrians, cyclists and motorcyclists) (Cameron, Newstead, & Le, 1999). This was later combined into a single index incorporating both other vehicle drivers and unprotected road users (S. Newstead, Watson, & Cameron, 2006). This study focuses on an analogous measure specific to pedestrians, which is the relative rate of fatal and serious pedestrian injuries involving the vehicle being rated compared to the rate of all pedestrian injuries involving the vehicle. In practice, a police-reported crash involving a pedestrian almost always involves an injury to the pedestrian, so the pedestrian aggressivity rating can be considered as the probability of pedestrian fatal or serious injury given that an injury has occurred for the pedestrian. A high value for this measure, all other things (including impact speed) being equal, is expected to be consistent with vehicle front-end structures that are relatively unforgiving, are geometrically unfavourable with respect to pedestrian impacts or promote unfavourable pedestrian dynamics in the collision. As impact speed is clearly a key factor in determining injury severity, any measure of pedestrian aggressivity must take this into account, for example by using the speed limit of the crash site as a proxy for impact speed.

Some emerging vehicle technologies are aimed specifically at preventing or reducing the severity of pedestrian injury, but most safety benefit may arise from technologies designed to reduce collision risk more generally, particularly those that are effective in lower speed limit areas where pedestrian crashes are focused. For example, Intelligent Speed Adaptation (ISA) assists compliance with speed limits either by warning the driver or actively slowing the vehicle control systems. It has the potential to reduce the risk of a wide range of crashes, including vehicle-pedestrian crashes, but its uptake may be limited by lack of acceptability to drivers who may resent its capacity to restrict speeds (Cairney, Imberger, Walsh, & Styles, 2010). Enhanced Night Vision similarly has some potential for reducing crashes with pedestrians at night, but the likely reductions in trauma cannot be estimated at present (Cairney et al., 2010). Collision Warning Systems' benefits are only currently evaluated by the manufacturers, and therefore have a limited perspective (Cairney et al., 2010). Similarly, active pedestrian detection systems have considerable potential, but the technology is relatively untested and has not been properly evaluated (Anderson, Hutchinson, Linke, & Ponte, 2010). An example of a general crash-reducing technology that is most effective at higher speeds is Electronic Stability Control (ESC), for which benefits do not appear to accrue for pedestrians according to a recent meta-analysis (Høye, 2011). This may be because vehicle loss of control/traction (the causes of crashes most benefited by ESC) plays a relatively minor role in pedestrian injuries.

A technology very specific to reducing pedestrian injury severity is pop-up hood (triggered by a sudden impact on the front bumper) and the windscreen airbag. Although these have been tested in the laboratory, it is uncertain what their real-life safety benefits would be. These are also difficult technologies to "sell" to the vehicle buyer as the safety benefits are provided to a third party, not one of the vehicle occupants. This may limit uptake, particularly for those systems that require potentially expensive repair when activated, unless regulation and/or crash testing protocols specify these technologies.

One technology applicable to a range of crash types that *has* been evaluated in terms of pedestrian safety is the Brake Assist System (BAS). This technology has been evaluated by Breuer et al. (2007) based on a study comparing crash involvement of vehicles fitted with BAS with a control group not fitted with BAC. They concluded that severe pedestrian accidents were reduced by 13% associated with the BAS technology, which is slightly higher than an estimate of 10% made by Page et al. (2005). According to Cairney (2010), brake assistance systems are now standard on a wide range of vehicles available in Australia, and presumably in New Zealand as well.

Road safety policy needs to focus on the components of a safe system, which includes safe road user behaviours, safe environments (such as roads), and safe vehicles. Vehicle fleets tend to change fairly slowly, as change in the fleets generally depends on the quality of new vehicles entering the fleet and of older vehicles removed from the fleet. Nevertheless, considerable safety gains have been estimated to accrue from improvements in fleet crashworthiness: the rate of killed and seriously injured drivers was estimated to have fallen by about 34% over a 10-year period due to vehicle fleet crashworthiness improvements alone (Keall, Newstead, & Jones, 2007).

This study sought to repeat some of the analysis carried out in the previous study of fleet crashworthiness, but focusing on pedestrian injury outcomes. The objective was to measure changes in pedestrian fatal and serious injury rates associated with gradual cross sectional changes in the light passenger vehicle fleet, and to project potential future changes in pedestrian fatal and serious injury rates that might arise with different scenarios of fleet changes and of safety technology uptake. The analytical steps included:

(i) estimate pedestrian aggressivity for subgroups of the fleet defined by make, model, market group and year of manufacture;

(ii) from changes occurring in the fleet, estimate the changes in pedestrian safety road trauma;

(iii) predict likely pedestrian safety effects arising from future changes to the fleet;

(iv) estimate what further safety gains might arise with the adoption of new technologies under various assumptions of effectiveness, and whether such gains may justify the expense of these technologies.

# 2 METHODS

## 2.1 DATA

There were four data sets analysed:

(i) **NZ pedestrian injury data** for the years 2004 to 2011 from reported crashes involving an injury for one of the involved road users were provided by the New Zealand Ministry of Transport. Only records for crashes involving light passenger vehicles (cars, SUVs and light commercial vehicles) were analysed, consisting of 6,547 vehicles involved in injuries to 7,753 pedestrians. Injuries not occurring on public roads, such as pedestrians injured on driveways that are private property, were not analysed as they are not officially within the scope of the Crash Analysis System.

(ii) **NZ vehicle Licensing data** for six years: 2003, 2004, 2006, 2007, 2008 and 2011 for a total of 18,162,993 vehicle-registration years (so the same vehicle could potentially appear in more than one year) were provided by the New Zealand Transport Agency. Each of six years of crash data was then matched to these snapshots of the licensing data as at the beginning of the crash year, which was necessary for the analysis since owner data and occasionally plate numbers can change for a given vehicle. Distance driven was estimated from a file providing the results of the periodic vehicle inspections, which are a requisite of licensing every year for vehicles within 8 years of manufacture, and six monthly subsequently. At the time of the inspection, the odometer reading is recorded, which provides the basis for the distance measure (estimating vehicle kilometres travelled, or VKT). The difference between two consecutive odometer readings that spanned at least six months of the year was then divided by the number of intervening days between the inspections and then annualised by multiplying by 365. Transcription errors in recording the odometer readings can yield negative or very large values for the estimated VKT using this method, so such values were flagged. The algorithm then either sought an adjacent odometer reading that yielded a feasible VKT estimate, or recorded a missing value for the vehicle. A missing value for VKT was recorded for 15% of the fleet.

(iii) **Pedestrian injury data from Australia and New Zealand** were used to estimate the pedestrian aggressivity ratings for different classes of vehicles. Data from Victoria, New South Wales, Queensland, South Australia, Western Australia and New Zealand used to produce the vehicle safety ratings of Newstead et al (2012) covering vehicles manufactured over the period 1964-2010 and crashing during the years 1987-2010 were used in the analysis. A subset of the data covered vehicles manufactured over the period 1982-2010 and crashing during the years 1987-2010 was used to estimate each of the pedestrian aggressivity measures. The combined data on pedestrians used for estimation of aggressivity covered 75,247 pedestrians, of whom 63,601 were injured. Of those injured, 22,301 with valid injury severity codes were seriously injured. These pedestrians were involved in a collision with a 1982-2010 model vehicle in Victoria during 1987-2010, NSW during 1987-1999, South Australia during 1995-2010, Queensland during 1991-2009 or in Western Australia or New Zealand during 1991-2010.

(iv) **Australian pedestrian injury data** was the base dataset used to calculate pedestrian aggressivity and fleet projections for Australia. Data used was the

Australian component of the data described under (iii) being data from Victoria, New South Wales, Queensland, South Australia, Western Australia covering vehicles manufactured over the period 1982-2010 and crashing during the years 1987-2010. The data covered 65,892 pedestrians, of whom 63,601 were injured. Of those injured, 19,524 were seriously injured.

## 2.2 CLASSIFYING VEHICLES

Each make and model of crash-involved passenger vehicle was classified into one of 10 market groups for analysis: Light (passenger car, hatch, sedan, coupe or convertible 3 or 4 cylinder engine, generally <1100kg); Small (passenger car, hatch, sedan, wagon, coupe or convertible 4 cylinder engine, generally 1100-1300kg tare mass); Medium (passenger car, hatch, sedan, wagon, coupe or convertible generally 4 cylinder engine, generally 1300-1550kg tare mass); Large (passenger car, hatch, sedan, wagon, coupe or convertible generally 6 or 8 cylinder engine, generally >1550kg tare mass); People Movers (non-SUV, seating capacity > 5 people); SUV Compact (<1700kg tare mass), SUV Medium (1700kg-2000kg tare mass) and SUV Large (>2000kg tare mass); Van; and Utility vehicles. Within market groups, vehicle make and model series were also classed into clusters of with as homogeneous engineering and equipment specification as possible. These clusters were identified either from detailed make and model descriptions and years of manufacture available in the vehicle registers from each jurisdiction or by decoding the Vehicle Identification Numbers (VINs) obtained through matching the crash data to registers of the licensed vehicles.

## 2.3 ESTIMATING PEDESTRIAN INJURY SEVERITY RATINGS FROM AUSTRALIAN AND NEW ZEALAND CRASH DATA

The measure of aggressivity towards pedestrians in this study is the risk of serious injury to the pedestrian given some injury was sustained in a crash. In practice, pedestrians are almost always injured when a crash involving them is reported to police, so the aggressivity measure for pedestrians is an estimate of the risk of death or serious injury to a pedestrian given involvement in a reportable crash. A logistic model was fitted with a response variable defined as 1 if the pedestrian was killed or hospitalised and 0 for lower severity injuries.

### 2.3.1 Adjusting for the Effects of Confounding Factors

Before adjusted aggressivity ratings could be obtained it was necessary to consider logistic models to identify possible factors, other than vehicle design, that might have influenced injury severity outcome to the pedestrian. A stepwise procedure was used to identify which factors had an important influence. This was done without considering the vehicle model, market group or year of manufacture of the passenger vehicle in the logistic model, as the aim was to determine which other factors were most likely to have an influence across a broad spectrum of crashes. The factors considered in the covariate models for aggressivity injury severity were:

- speed limit at the crash location ( <80km/h, >= 80 km/h)
- pedestrian age (<=25 years, 26-59 years, >=60 years)
- pedestrian sex (male, female)
- jurisdiction in which the crash occurred (VIC, NSW, WA, QLD, SA, NZ)

- year in which the crash occurred (1987, … ,2010)

These variables were chosen for consideration because they were available in each of the New South Wales, Victorian, Western Australia, Queensland and New Zealand crash databases and had been found from prior research to be associated with the injury outcome. Logistic regressions were carried out using Proc Logistic from the SAS statistical package (SAS Institute Inc, 2004), employing maximum likelihood estimation with stepwise selection of variables, including all interactions.

### 2.3.2 Formulation of Specific Ratings

Pedestrian aggressivity by passenger vehicle model, passenger vehicle market group, passenger vehicle year of manufacture and grouped year of manufacture by market group were each estimated after adding a categorical variable representing the vehicle model, vehicle market group, vehicle year of manufacture or grouped year of manufacture by market group respectively to the logistic covariate model. The variables representing vehicle model, vehicle market group, vehicle year of manufacture or grouped year of manufacture by market group were forced into the logistic regression model and individual vehicle model, vehicle market group, vehicle year of manufacture or grouped year of manufacture by market group coefficients were computed to represent deviations of levels of each factor considered from the average. To ensure logistic model convergence, vehicle models, market groups, year of manufacture or grouped year of manufacture by market group were excluded for the calculation of the aggressivity ratings if there were less than 100 vehicles that had impacted a pedestrian or there were less than 20 injured pedestrians.

### 2.3.3 Pedestrian aggressivity ratings by vehicle model for light passenger vehicles

After exclusions based on the quantity of data for each car model the regression analysis for vehicle models was performed on 96 individual car models (or pooled similar models) that met the criteria. The variable representing vehicle model was therefore categorical with 96 nominal levels. Parameterisation of the logistic model allowed the injury severity estimates for each vehicle model to be compared with the overall (average) rating for all vehicle models. For each vehicle model, a 95% confidence interval for the vehicle model parameter was obtained from the logistic regression model output. Estimates of injury severity were obtained by setting the non-vehicle related factors in the logistic regression model at an average profile for the data and then applying the reverse logistic transform. A 95% confidence interval for the injury severity estimate was derived through applying the reverse logistic transform to the 95% confidence interval for the vehicle model parameter using the same average profile of other factors in the logistic model.

### 2.3.4 Pedestrian aggressivity ratings by vehicle market group for light passenger vehicles

For vehicle market group there were no exclusions based on data quantities and the regression analysis was performed on 10 market groups. The variable representing market group was therefore categorical with 10 nominal levels and replaced the vehicle model variable in the logistic regression model. Point estimates of injury severity by market group and corresponding 95% confidence limits were derived in the same way as for the vehicle model estimates.

### 2.3.5 Pedestrian aggressivity ratings by vehicle year of manufacture for light passenger vehicles

For vehicle year of manufacture there were also no exclusions based on data quantities and the regression analysis was performed on 29 years of manufacture from 1982 to 2010. The variable representing year of manufacture was therefore categorical with 29 nominal levels. Point estimates and 95% confidence limits of injury severity by year of manufacture were obtained in the same way.

### 2.3.6 Pedestrian aggressivity ratings by grouped year of manufacture and vehicle market group for light passenger vehicles

As a result of sparse data it was not possible to determine pedestrian aggressivity ratings by individual year of manufacture and market group without a large number of exclusions due to groups of fewer than 100 vehicles in pedestrian crashes, or with fewer than 20 injured pedestrians. To overcome this, vehicle year of manufacture was grouped into six categories consisting of years of manufacture 1982-1986, 1987-1991, 1992-1996, 1997-2001, 2002-2006 and 2007-2010. A variable representing the year of manufacture ranges and vehicle market group was forced into the model. Two combinations did not satisfy the inclusion criteria and the analysis was performed on 58 grouped year of manufacture and market group combinations.

## 2.4 NEW ZEALAND VEHICLE FLEET EFFECTS ANALYSIS

### 2.4.1 Allocating aggressivity ratings to the New Zealand fleet

Reflecting the range of logistic models described above, there are a number of resolutions at which vehicle secondary safety rating information can be applied to light passenger and light commercial vehicles appearing on the New Zealand vehicle register. They are (in descending order of specificity):

- By specific make and model
- By (grouped) year of manufacture and market group
- By year of manufacture only

Table 1 shows coverage of the registered New Zealand light vehicle fleet as recorded on the Motor Vehicle Register in 2003-2011 which can have pedestrian injury severity estimates applied at various levels of detail. It shows that 19% of the fleet (predominantly newer vehicles) had this rating applied by make and model. Vehicles manufactured before 1982 were not assessed because of the large degree of heterogeneity amongst such vehicles and their rarity in the fleets. These older vehicles were the main constituent of the final level of identification shown in Table 1, where no estimate was allocated.

**Table 1: Level of assigning pedestrian severity estimates to light vehicles in the New Zealand light passenger fleets 2003-2011**

| Level of identification | Method | N | Proportion of fleets |
|---|---|---|---|
| 1 | Make/model direct | 3,488,605 | 19% |
| 2 | Market group and year of manufacture | 13,473,319 | 74% |
| 3 | Year of manufacture only | 756,134 | 4% |
| 4 | Not assigned | 444,935 | 2% |

### 2.4.2 Matching of vehicles involved in pedestrian crashes with register of licensed vehicles to estimate pedestrian crash rates by fleet characteristics

A match between the number plate of the vehicle involved in pedestrian crashes (as recorded in the Crash Report completed by Police) was made with the plate numbers of the licensed fleet, where possible. There were a total of 6,547 light passenger vehicles recorded as involved in pedestrian crashes, of which no match was possible for 1,370 vehicles (21%). Reasons for non-matches include that the vehicle was not licensed at the time of the crash; the vehicle was licensed at the time of the crash, but not licensed at the time the extract (snapshot) of the register was made; errors in recording the plate number; failure to record the field in the Crash Report. There were 268 with missing plate numbers, 20% of the non-matched vehicles. It was not possible to determine the precise cause of non-matching for the remaining 80%.

The analysis of the matched crash and licensed vehicle registers estimated rates of vehicles colliding with and injuring pedestrians. On relatively rare occasions, more than one vehicle was involved in the same crash resulting in a pedestrian injury. This might occur when one vehicle collides with another, resulting in a subsequent collision with a pedestrian. Or a vehicle might brake or swerve suddenly to avoid a pedestrian, leading to a collision with another vehicle as well as the pedestrian. Rather than undertake a relatively complex analysis of these rare multi-vehicle crashes, each vehicle in a two-vehicle crash with a pedestrian was allocated half that injury (i.e. a half weight in the analysis). There were also rare occasions whether more than one pedestrian was injured in the one crash.

### 2.4.3 Estimating safety gains for pedestrians

Once the fleets had been allocated estimates of pedestrian aggressivity at the levels of identification shown in Table 1, the improvements in injury outcomes due to improvements in the fleet over time could then be estimated. An annual improvement was estimated from the fleet average aggressivity, taking values of say x and y for two consecutive years. These represent the probability of fatal or serious injury to the pedestrian related to vehicle design factors given that the pedestrian has been injured in a reported crash. A reduction from one year to the next related to improvements in pedestrian aggressivity of vehicles represents a reduction in the proportion of pedestrian fatal and serious injuries of (x-y)/x.

### 2.4.4 Log-binomial regression analysis to predict future safety levels

Models were fitted to estimate the way that the overall risk of fatal and serious pedestrian injury (given that an injury occurred) changed with time. Estimation of risk ratios using a generalised linear model with a log link function and binomial distribution has been called log-binomial regression by Blizzard and Hosmer (2006). This approach was appropriate for modelling trends in the risks of fatal and serious injury. As was done in a previous project involving predicting the safety performance of the fleet (Keall et al., 2007), this analysis did not attempt to use all available variables in the predictive models, but only used those factors that were of interest in building scenarios of change. These factors included the market group distribution of the fleet (as different market groups have clearly different potential to impose risk on pedestrians), the age of the fleet (as initial analysis showed clear improvements in safety for pedestrians for later model vehicles), and the potential for future further safety improvements beyond those already seen. Once the parameters for the models were estimated from past data, the safety effects of future potential changes in the fleets could then be predicted. Models were fitted using the SAS procedure GENMOD (SAS Institute Inc, 2004).

## 2.5 AUSTRALIAN ANALYSIS

### 2.5.1 Allocating aggressivity ratings to the Australian fleet

Pedestrian severity estimates were applied to light passenger vehicles in the Australian pedestrian injury data described under Section 2.1using a similar hierarchy of assignment as used for the New Zealand data (in descending order of specificity):

- By specific make/model and year of manufacture
- By market group and (grouped) year of manufacture

The Australian analysis differed from the New Zealand analysis in that it required a vehicle to have an assigned market group for the analysis methodology to be able to be applied. Vehicles without an assigned market group were excluded from the analysis.

Table 2 shows coverage of the Australian pedestrian injury data with pedestrian injury severity estimates applied at various levels of detail. It can be seen that a majority of cases (67%) had the rating applied by specific make/model and year of manufacture. The final level of Table 2 shows that there were 6,529 cases where market group was unknown. As such, these cases were not included in the analysis leaving 59,430 cases with vehicles manufactured over the period 1982-2010 and crashing during the years 1987-2010.

**Table 2: Level of assigning pedestrian severity estimates to the Australian pedestrian injury dataset 1987-2010**

| Level of identification | Method | N | Proportion of data |
|---|---|---|---|
| 1 | Specific make/model and year of manufacture | 43,893 | 67% |
| 2 | Market group and year of manufacture (grouped) | 15,470 | 23% |
| 3 | Market group unknown | 6,529 | 10% |

### 2.5.2 Australian fleet pedestrian aggressivity and fleet projections

Once the Australian pedestrian injury dataset had been allocated estimates of pedestrian aggressivity at the levels of identification shown in Table 2, pedestrian aggressivity of the Australian fleet could be calculated followed by fleet projections allowing future savings in injury crashes due to improvements in the fleet to be estimated. Firstly, average fleet aggressivity was calculated by market group per year of crash for the period 1987-2010. Fleet composition by market group per year of crash was also calculated for the same period. Projections of fleet aggressivity and fleet composition were then made for each market group series for the period 2011-2020. These projections were achieved by firstly fitting structural time series models for the period 1987-2010 using the STAMP software package (Koopman, 2007), then forecasting each market group series over the period 2011-2020. Fleet aggressivity and fleet composition were then combined and summed across market group to determine actual or projected total fleet pedestrian aggressivity for the period of 1987-2020.

# 3 RESULTS

The following section presents analysis of: the New Zealand injury data analysed and estimates of New Zealand pedestrian injury rates per vehicle and per distance driven by vehicle market group and year of manufacture; trends in injury severity ratings for the New Zealand and Australian fleet; the estimated influence of market group composition and age distribution of the fleet on pedestrian injury severity; estimates of injury savings due to changes in the fleet; estimates of projected injury savings under certain scenarios; penetration of safety effects into the fleet from a scenario of an emerging safety technology installed in all new vehicles; social costs of pedestrian injury in New Zealand and Australia and the per-vehicle expense justified to prevent such injury.

**New Zealand pedestrian injury data**

Table 3 summarises the pedestrian injury data analysed, along with the proportion of injured pedestrians who were either killed or hospitalised. The proportion that were fatally injured or hospitalised appears to have fallen over the period studied, from a level of about 30% in the first part of the period, to about 26% in the last two years.

**Table 3: Number of injured pedestrians in reported crashes involving motor vehicles on New Zealand public roads 2004-2011, with percentage who were fatally and seriously injured**

| Year | Fatalities | Hospitalised (“serious”) | Medically treated (“minor”) | Total injured | Proportion fatal & serious |
|---|---|---|---|---|---|
| 2004 | 38 | 270 | 729 | 1,037 | 30% |
| 2005 | 31 | 248 | 704 | 983 | 28% |
| 2006 | 44 | 265 | 694 | 1,003 | 31% |
| 2007 | 45 | 232 | 636 | 913 | 30% |
| 2008 | 31 | 260 | 678 | 969 | 30% |
| 2009 | 31 | 233 | 681 | 945 | 28% |
| 2010 | 35 | 230 | 737 | 1,002 | 26% |
| 2011 | 31 | 204 | 666 | 901 | 26% |
| **TOTAL** | **286** | **1,942** | **5,525** | **7,753** | **29%** |

Table 4 shows the number of licensed vehicles recorded on the motor vehicle register, totalled across the eight years studied (2004-2011). Distance driven (VKT) and injured pedestrians (with vehicle matched to register) in reported crashes involving motor vehicles on New Zealand public roads 2004-2011, with rate per vehicle and per distance driven, overall and by market group. Different factors can lead to higher rates of pedestrian injury, including the way the vehicle is driven and vehicle factors, such as the geometry of the front of the vehicle, which most commonly impacts the pedestrian. However, an important factor will be where the vehicle is commonly used. Those vehicles commonly used on urban roads during the daytime will experience high rates of pedestrian injury simply because of high levels of exposure to pedestrians on the road. Table 4 shows high rates estimated for vans, light cars, large cars and people movers; low rates were estimated for utility vehicles (known as pickup trucks in the US) and SUVs.

**Table 4: Licensed vehicle-years, travel exposure, police reported injured pedestrians and injury rates in reported crashes involving motor vehicles: New Zealand 2004-2011 by vehicle market group**

| Market group | N | Mean annual km (VKT) | Pedestrians injured** | Injury rate / 1000 vehicles* | Injury rate / 100 mil VKT |
|---|---|---|---|---|---|
| missing | 1,405,413 | 10,035 | 1,576 | | |
| Utility vehicles | 297,761 | 12,587 | 27 | 0.09 | 0.7 |
| Van | 277,923 | 12,728 | 90 | 0.32 | 2.5 |
| Large | 3,496,265 | 13,084 | 1,018 | 0.29 | 2.2 |
| Medium | 4,881,448 | 12,207 | 1,308 | 0.27 | 2.2 |
| PM | 718,203 | 13,757 | 204 | 0.28 | 2.1 |
| Small | 6,019,635 | 10,974 | 1,649 | 0.27 | 2.5 |
| Light | 1,851,363 | 9,979 | 534 | 0.29 | 2.9 |
| SUVC | 930,704 | 12,686 | 92 | 0.10 | 0.8 |
| SUVL | 425,964 | 14,348 | 20 | 0.05 | 0.3 |
| SUVM | 987,525 | 13,895 | 62 | 0.06 | 0.4 |
| **Overall** | **21,292,204** | **11,910** | **6,577** | **0.31** | **2.6** |

*where more than one vehicle was involved in a given collision with a pedestrian, the injury was allocated equally to each vehicle to facilitate the computation of a rate

**this only counts injured pedestrians for which a vehicle involved could be matched to the motor vehicle register

**Table 5: Licensed vehicle-years, travel exposure, police reported injured pedestrians and injury rates in reported crashes involving motor vehicles: New Zealand 2004-2011 by vehicle year of manufacture group**

| Year of manufacture+ | N | Mean annual km (VKT) | Pedestrians injured** | Injury rate / 1000 vehicles* | Injury rate / 100 mil VKT |
|---|---|---|---|---|---|
| 1891-1970 | 403,613 | 2,909 | 15 | 0.04 | 1.2 |
| 1971-1980 | 430,592 | 4,050 | 25 | 0.06 | 1.4 |
| 1981-1990 | 3,511,570 | 8,781 | 1,053 | 0.30 | 3.4 |
| 1991-1995 | 6,027,252 | 11,164 | 1,932 | 0.32 | 2.9 |
| 1996-2000 | 6,110,291 | 12,475 | 1,799 | 0.29 | 2.4 |
| 2001-2005 | 3,306,590 | 14,113 | 944 | 0.29 | 2.0 |
| 2006-2012 | 1,501,663 | 16,941 | 378 | 0.25 | 1.5 |
| **Overall** | **21,292,201** | **11,910** | **6,577** | **0.31** | **2.6** |

+two vehicles had missing year of manufacture

*where more than one vehicle was involved in a given collision with a pedestrian, the injury was allocated equally to each vehicle to facilitate the computation of a rate

**this only counts injured pedestrians for which a vehicle involved could be matched to the motor vehicle register

## 3.1 ESTIMATES OF PEDESTRIAN INJURY SEVERITY RATINGS

**Figure 1: Pedestrian injury severity rating (probability of fatal or serious injury given an injury occurred) by year of manufacture of vehicles 1982 to 2010 with 95% confidence intervals**

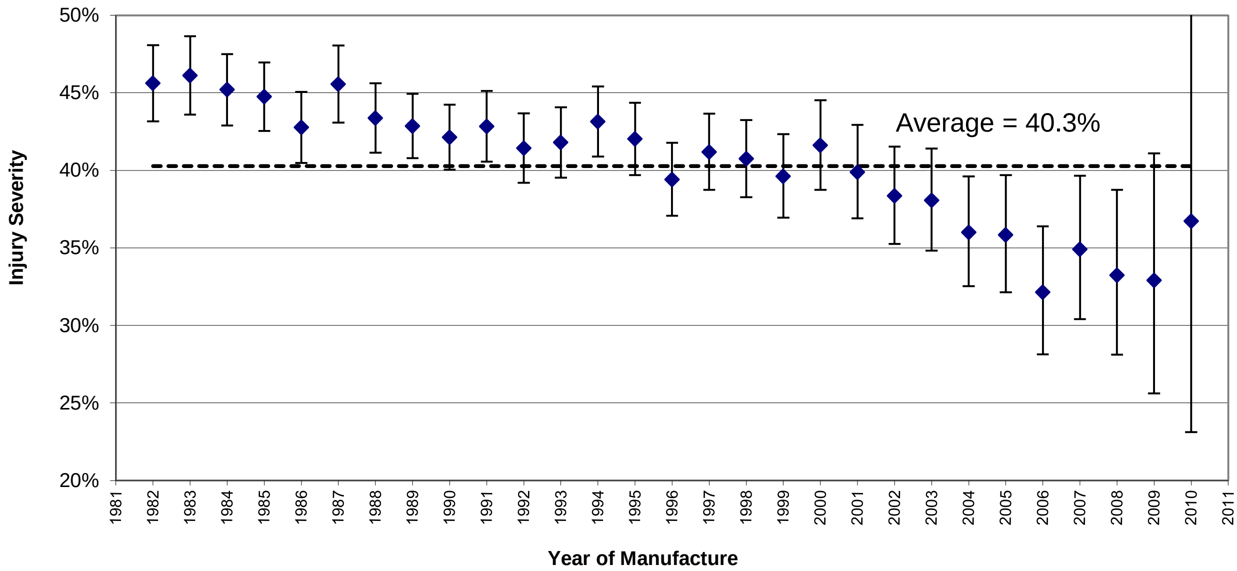



Figure 1 shows estimated injury severity risks for each year of manufacture from 1982 to 2010, estimated from combined New Zealand and Australian data. This shows a clear trend of improving injury outcomes. There is greater uncertainty with the estimates over the last decade shown, as indicated by wider confidence intervals, due to fewer crashes available to analyse.

## 3.2 ANALYSIS OF CHANGES IN THE INJURY SEVERITY RATINGS OF THE NEW ZEALAND VEHICLE FLEET

As described above in the Methods section, 98% of the New Zealand light vehicle fleet was matched to pedestrian injury severity ratings by make and model, market group and year of manufacture, or just by year of manufacture. This meant that analysis could be made of the injury savings (prevention of fatal or serious injury) attributable to improvements in the fleet with respect to pedestrian impacts. Such savings can arise from three main factors modelled:

- the age distribution of the fleet (proportion of newer model vehicles compared to older vehicles);
- the market group mix of the fleet (as some vehicles types impose greater risks on pedestrians);
- an overall improvement over time (representing general improvements in vehicle construction to reduce risks to pedestrians).

These estimated parameters for specified levels of these factors are shown inTable 6, with the relative rating (which is the respective severity rating divided by the reference level severity rating) shown in the last column. These represent the effects of each given factor on the injury severity rating while controlling for the effects of the other factors modelled.

For example, controlling for the other factors, it was estimated that a recent model vehicle (manufactured within five years of the year of the fleet snapshot) in a given market group in a given year's fleet had only 82.1% of the risk of a fatal or hospitalised injury compared to a vehicle aged 40 plus in the same market group and fleet year. The ratings become closer to the ratings estimated for the oldest age group as the vehicles got older. Similarly, with each additional year of fleet (e.g. those vehicles in the fleet in 2008 compared to the vehicles sharing the same levels of the parameters in 2007), it was estimated that risk fell by 0.9% (the last row of the table, showing a relative risk rating of 0.991, which is 0.9% less than 1).

**Table 6: Estimates from log-binomial regression analysis of pedestrian injury severity ratings for NZ fleets 2003-2011**

| Parameter | | Estimated coefficient | Relative rating |
|---|---|---|---|
| Intercept | | -0.7006 | |
| Vehicle age vs. 40 plus | <5 | -0.1976 | 0.821 |
| | 5-9 | -0.1084 | 0.897 |
| | 10-14 | -0.0754 | 0.927 |
| | 15-19 | -0.0458 | 0.955 |
| | 20-24 | -0.013 | 0.987 |
| | 25-39 | -0.006 | 0.994 |
| Market group vs. SUV Medium | Utility vehicle* | 0.0485 | 1.050 |
| | Van | -0.0886 | 0.915 |
| | Large car | -0.1509 | 0.860 |
| | Medium car | -0.1278 | 0.880 |
| | People Mover | -0.0339 | 0.967 |
| | Small car | -0.0912 | 0.913 |
| | Light car | -0.1415 | 0.868 |
| | SUV Compact | -0.0046 | 0.995 |
| | SUV Large | -0.0692 | 0.933 |
| Year of fleet | (per year) | -0.0086 | 0.991 |

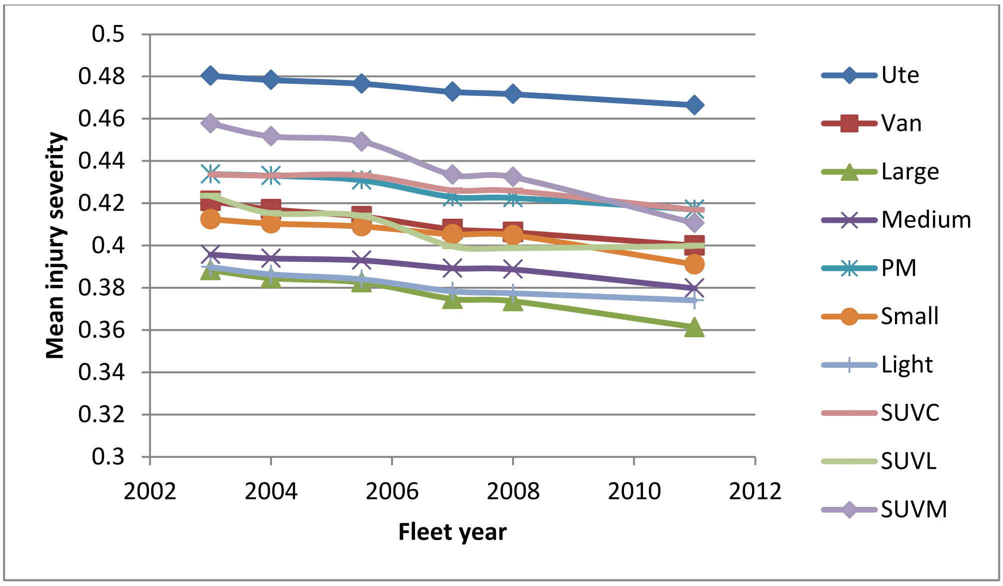
*known as pick-up trucks in the US

## 3.3 RETROSPECTIVE EFFECTS ON PEDESTRIAN SAFETY

### 3.3.1 New Zealand model fit

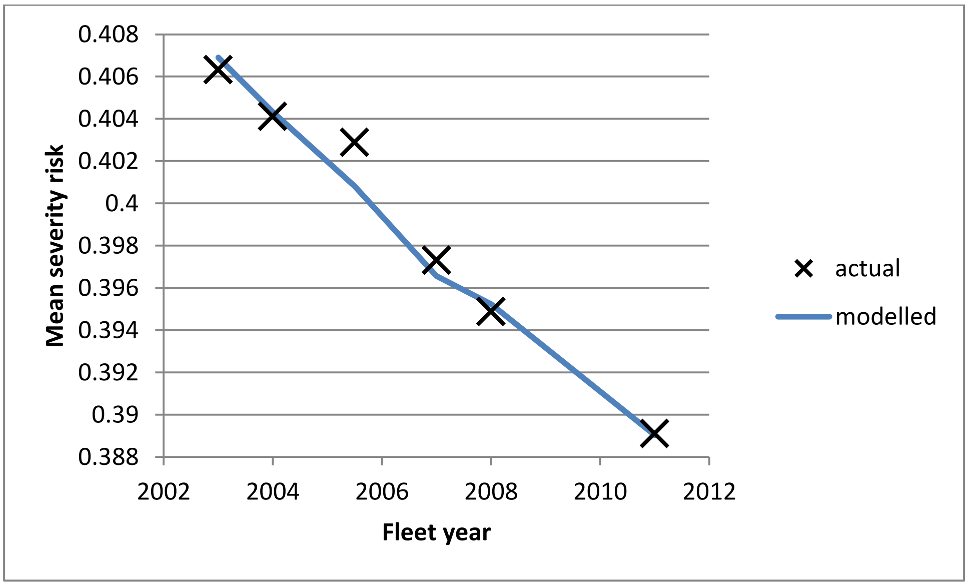
Figure 2 shows analysis of the estimated average pedestrian severity risk imposed by the New Zealand fleets over the period 2003 to 2011 by market group of the vehicle. These show that the fleet severity risk has fallen consistently for all market groups. In terms of the way the model parameters were fitted, the age distribution within market groups is not made transparent by the graph, so such effects will have affected the market group orderings and the trends to some extent. The general trend by fleet year, represented by the parameter and associated estimate in the bottom line of Table 6, can be thought of approximately as an average of the trend shown by the 10 series shown in the graph (with greater influence asserted by the larger market groups, such as small and medium cars). The relative injury severity rating of the market groups (with commercial utes clearly worst-performing) as shown in the graph is averaged across the fleet years in the 9 rows above the bottom line of Table 6.

**Figure 2: Pedestrian injury severity rating (probability of fatal or serious injury given an injury occurred) by market group of vehicle and fleet year**



The adequacy of the model based on the characteristics of the fleet to estimate mean pedestrian injury severity was assessed through comparing actual injury severity averaged across the entire fleet for each fleet year considered (shown as the crosses in Figure 3) to estimates of these values from the model. Estimates were derived using the fleet characteristics listed above (proportion of fleet in each market group; proportion in each age group; the year of the fleet) and are shown as the line in Figure 3. There is clearly a very good fit between the actual fleet averages and the averages predicted by the model. The reduction in the fleet average injury severity for pedestrians shown here represents an annual saving of at least 14 fatal and serious injuries for the 2011 fleet compared to the 2003 fleet. Aggregated across the entire period from 2003-2011, this amounts to a saving of 37 fatal and serious injuries. Some of these injuries can be considered to have been *reduced* in severity and become "minor" injuries (that require medical treatment, but not hospital admission). It is also possible that some minor injuries that would have occurred in 2003 may have been prevented under the same conditions (but somewhat different vehicle fleet) in 2011. If this is the case, then the estimated saving of 14 fatal and serious injuries will underestimate the actual savings.

**Figure 3: Pedestrian injury severity rating averaged across the fleets 2003 to 2011 (crosses) and as predicted by the model based on fleet characteristics (line)**




### 3.3.2 Australian data

After allocation of the Australian pedestrian injury dataset with estimates of pedestrian aggressivity for each crash involved vehicle, average Australian fleet aggressivity was calculated by market group and year of crash for the period 1987-2010 (Figure 4). In addition, the pedestrian injury dataset was used to calculate Australian fleet composition by market group and year of crash for the period 1987-2010 (Figure 5).

**Figure 4: Average Australian fleet aggressivity by market group and year of crash 1987-2010**

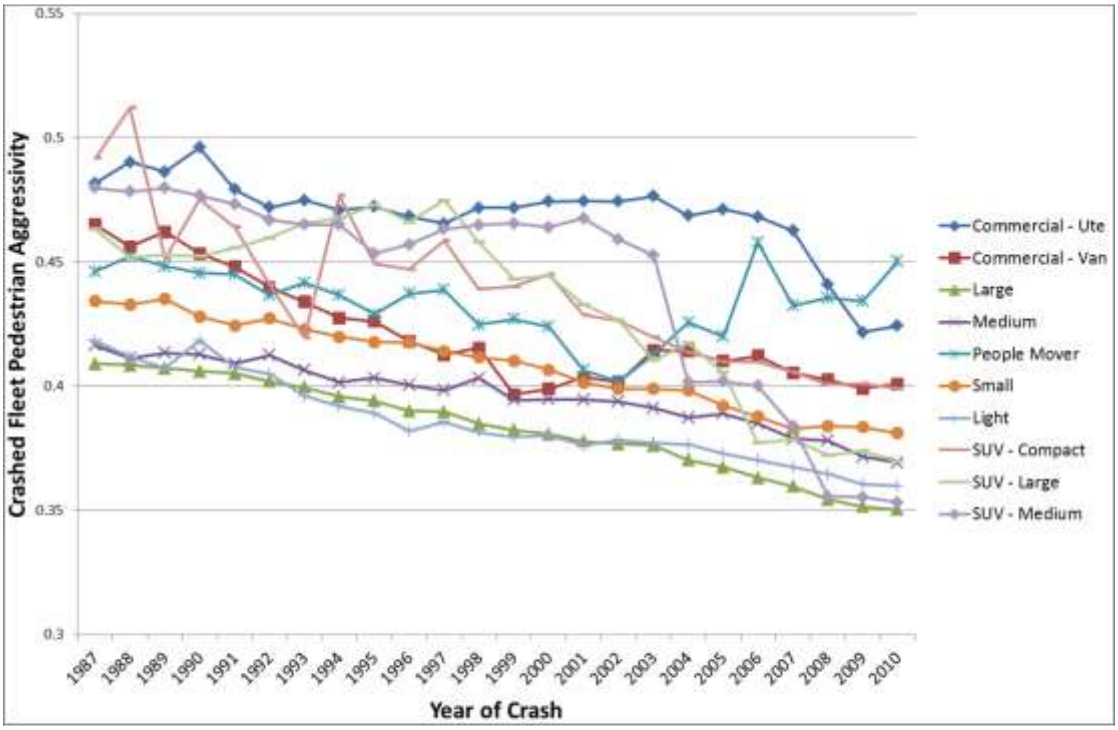
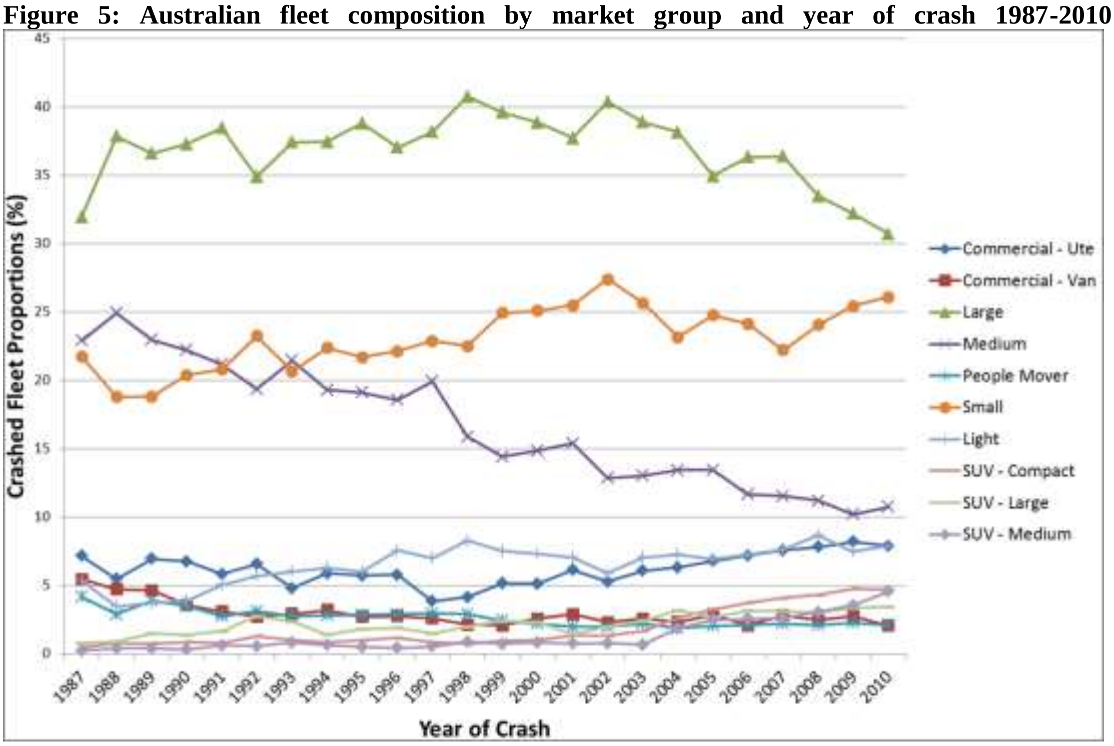


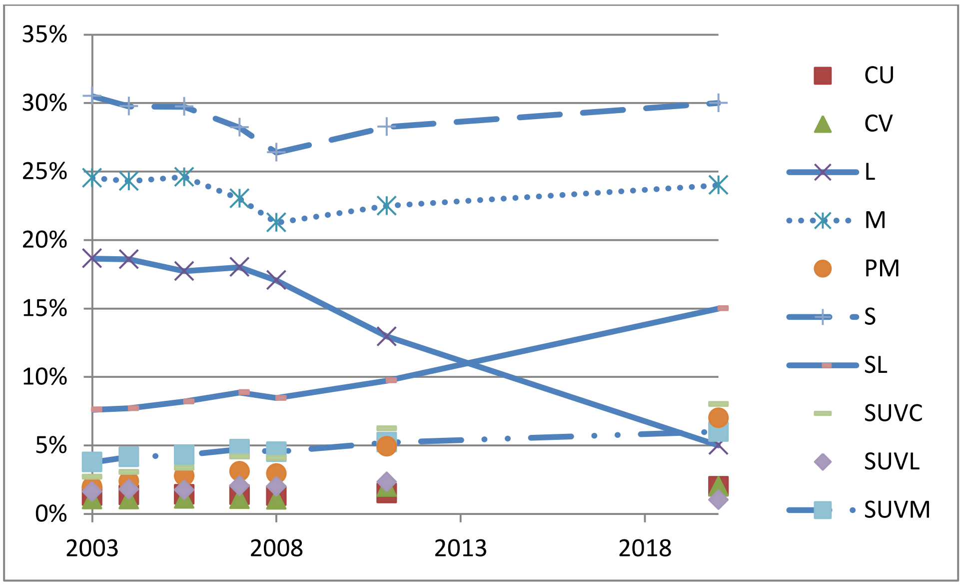

**Figure 5: Australian fleet composition by market group and year of crash 1987-2010**



## 3.4 SCENARIOS TO PREDICT FUTURE NEW ZEALAND FLEET PEDESTRIAN INJURY SEVERITY RATINGS

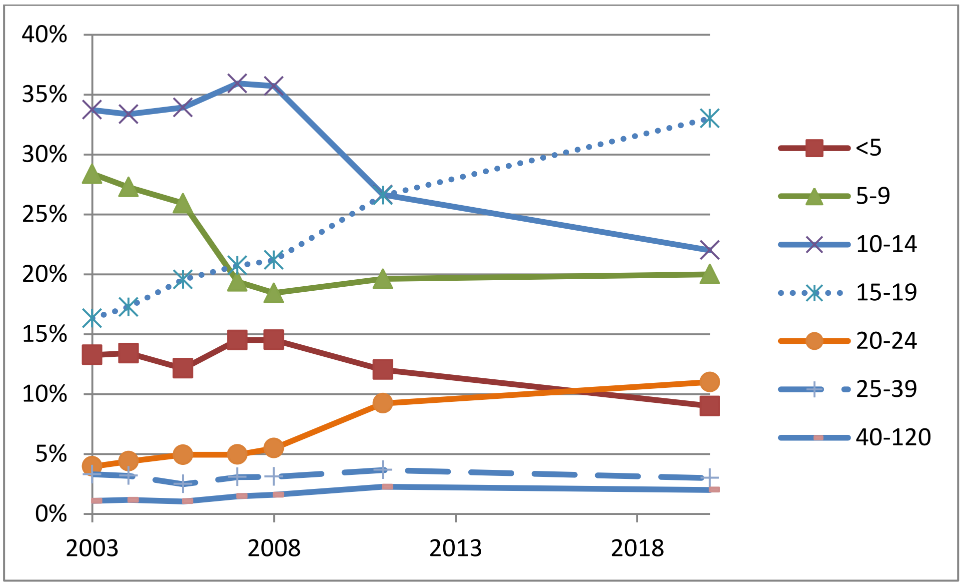
The next stage of the analysis involved creating scenarios of potential change in the fleet based on the characteristics: the market group composition of the fleet; the age distribution of the fleet; and the way that vehicles may (or may not) continue to improve in terms of their pedestrian injury severity ratings. Figure 6 shows the proportion of the fleet in each of the 10 market groups over the period 2003 and 2011, with a projection made for 2020 based on existing trends. It was also anticipated that future petrol price increases may lead buyers to favour smaller vehicles, as has happened when petrol prices have risen in the past. Note that the vehicle market groups that will have most effect on the fleet average will be those with greatest representation in the fleet: small cars, medium cars and light cars.

**Figure 6: Composition of NZ fleet by market group, with projected potential "business as usual" composition in the year 2020**



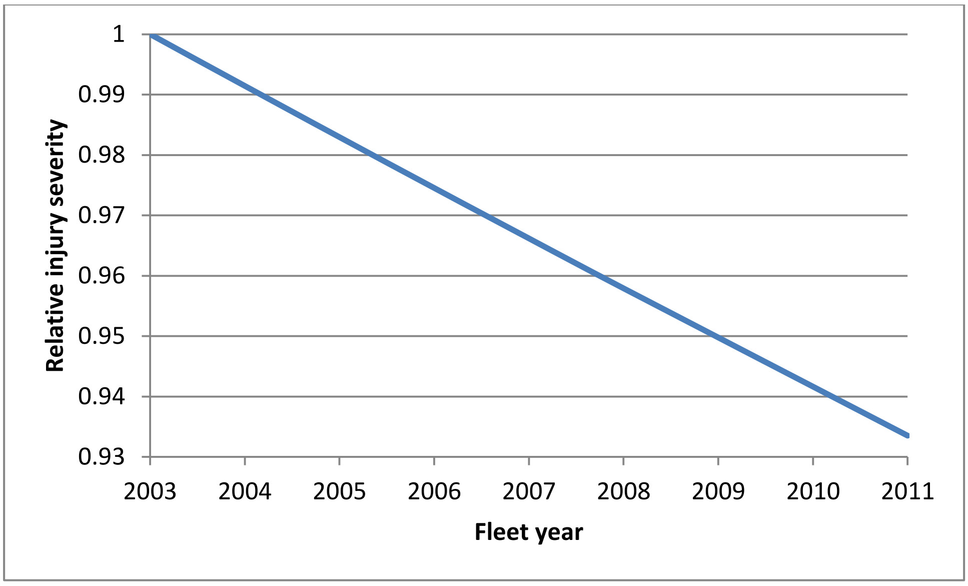

Similar to Figure 6, Figure 7 shows the proportion of the fleet in seven age bands as analysed for the fleets between 2003 and 2011, with a projection made until 2020 based on existing trends, along with an anticipation of future economic conditions that might lead people to buy second-hand vehicles rather than new vehicles, and hold on to older vehicles longer. Note that New Zealand imports a large number of second-hand vehicles from Japan, so the proportion of older vehicles can grow independently of the proportion of new vehicles entering the fleet. In this projection, the proportion of new vehicles (aged less than 5 years) falls slightly, the proportion of vehicles 10-14-years-old also falls, compensated for by an increase in the proportion of vehicles aged 15-19 years.

**Figure 7: Composition of NZ fleet by vehicle age, with projected potential "business as usual" composition in the year 2020**




The final parameter that is considered in the creation of the scenarios relates to the ongoing improvement in injury severity imposed on pedestrians related to vehicle design as averaged across the vehicle market groups and across the age bands. Figure 8 shows the model-based estimate of the relative injury severity, with the average risk for the 2003 fleet indexed to 1. As discussed above in relation to the model parameter estimates shown in Table 6, this represents a 0.9% reduction in risk with each additional year of fleet. In two of the scenarios described in this paper, it is assumed that this incremental improvement continues, but the last scenario proposes a flattening of this line such that vehicles newer than 2011 models cease to improve with respect to pedestrian injury severity.

**Figure 8: Model-based estimate of the trend in relative severity risk against fleet year, with the average risk for the 2003 fleet indexed to 1**



## 3.5 NEW ZEALAND SCENARIOS AND THEIR CONSEQUENCES FOR PEDESTRIAN INJURY

In the following sub-section, three scenarios of changes to the New Zealand fleet are described along with their predicted impact on pedestrian injury severity.

### 3.5.1 Business as usual: variant 1

This scenario uses past changes in the fleet and trends in fleet safety with respect to pedestrians to predict likely outcomes in 2020. The inputs to the model are those shown in Figure 6 and Figure 7 along with a predicted improvement in aggressivity (injury severity) as modelled by a continuation of the line in Figure 8. The projected change in mean fleet injury severity for pedestrians is shown in Figure 9. This indicates that the mean injury severity is predicted to fall from 0.389 to about 0.365 from 2011 to 2020. Using this scenario, the changes in the numbers of fatal and serious pedestrian injuries were also predicted. Figure 10 indicates that relative to the 2003 fleet, the 2020 fleet may save at least 32 fatal and serious injuries per annum (all other things being equal: assuming that vehicle and pedestrian activity do not change drastically over that period).

**Figure 9: Business as usual scenario, with actual fleet mean injury severity risk (circles) and modelled severity risks (line) to the year 2020**

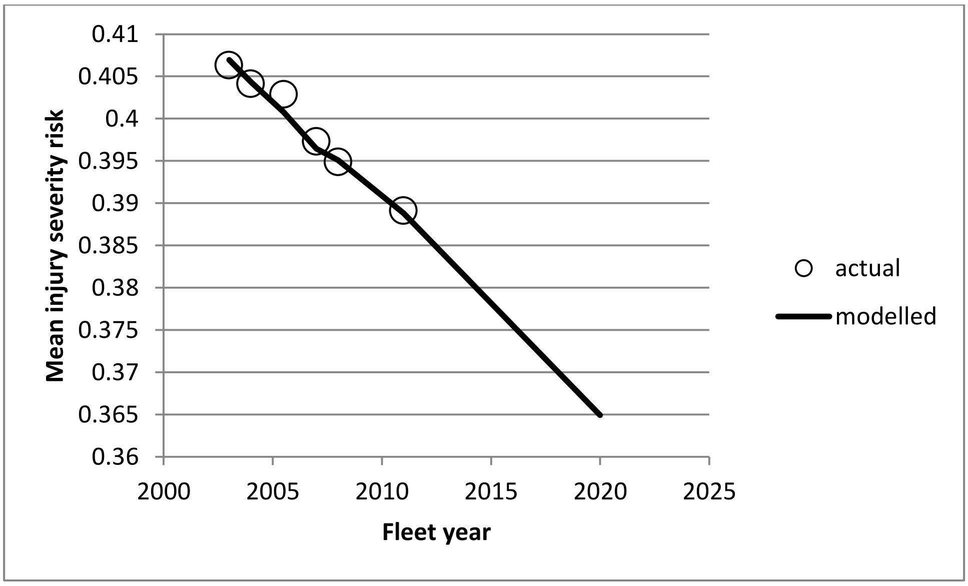
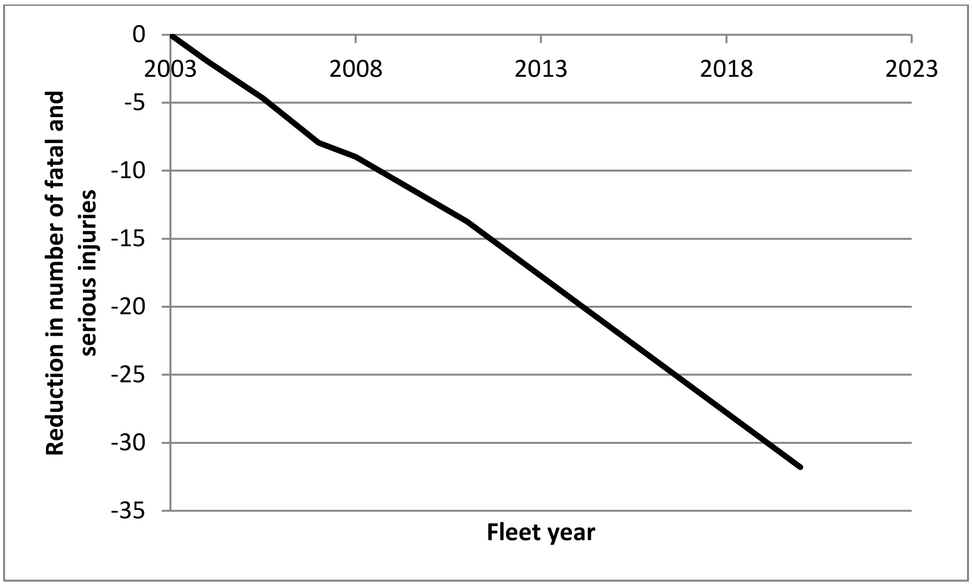


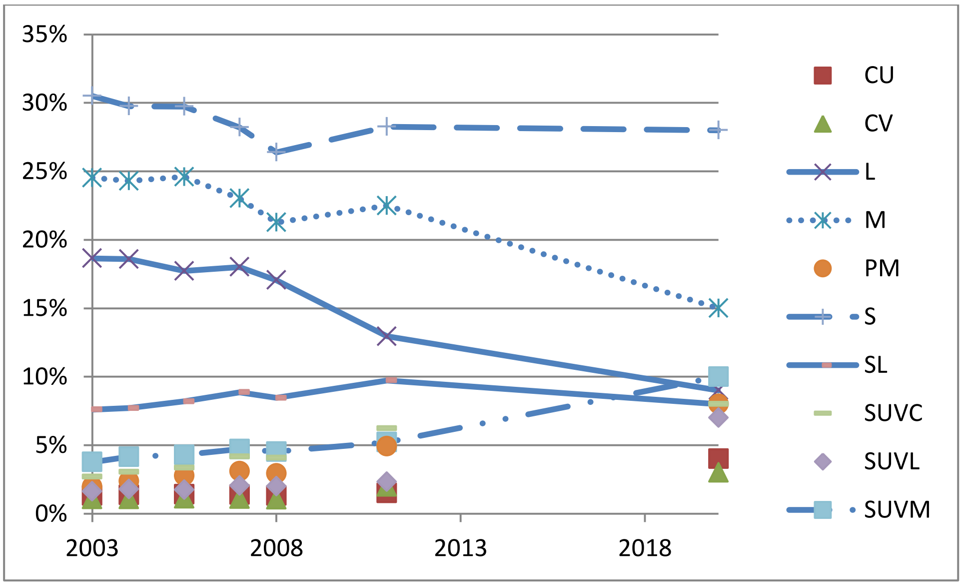
**Figure 10: Business as usual scenario: reduction in absolute annual pedestrian fatal and serious injuries due to fleet changes projected to the year 2020**




### 3.5.2 Business as usual: variant 2

Figure 11 shows another potential variant of the business as usual scenario. This time, there is less of a drop in the proportion of large cars in the fleet, an increase in SUVs, and a drop in medium cars. The age distribution is kept the same as in subsection 3.5.1. The modelled mean fleet injury severity risk for the year 2020 was estimated to be 0.37 and the estimated annual savings in pedestrian fatal and serious casualties was estimated to be 28. From the relatively similar projections of the first two scenarios, it is apparent that the projected injury savings are relatively robust to potential changes in the fleet composition in terms of market groups.

**Figure 11: Composition of NZ fleet by vehicle market group, with projected potential business as usual (variant 2) composition in the year 2020**



### 3.5.3 No further improvement and fleet as in business as usual: variant 1

The inputs to the model are those shown in Figure 6 and Figure 7 along with a predicted stalling in improving safety as modelled by a flattening of the line in Figure 8 from 2011 onwards. This scenario yielded estimated annual savings in pedestrian fatal and serious casualties for the 2020 fleet of 27 (see Figure 12 and Figure 13).

**Figure 12: No further improvement with fleet business as usual scenario, with actual fleet mean injury severity risk (circles) and modelled severity risks (line) to the year 2020**

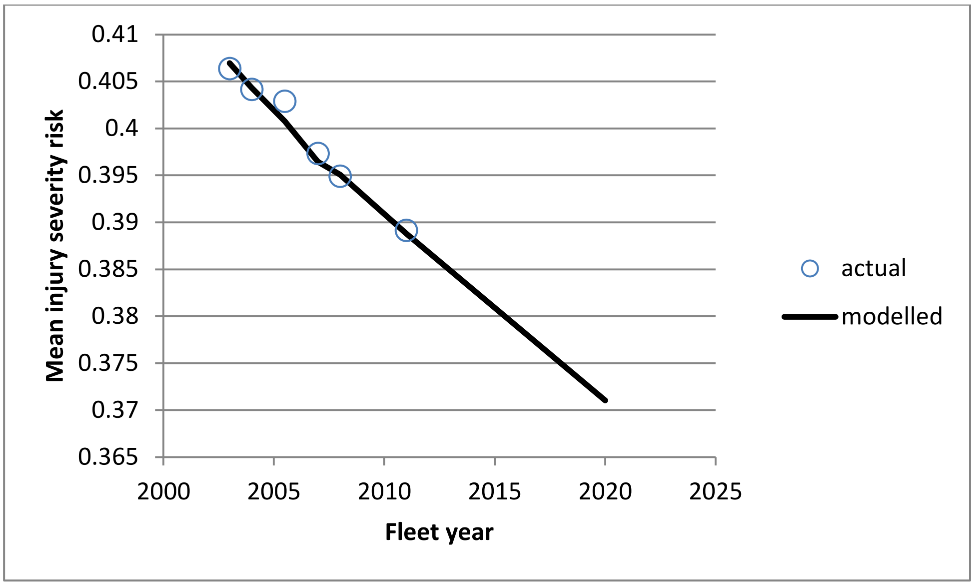
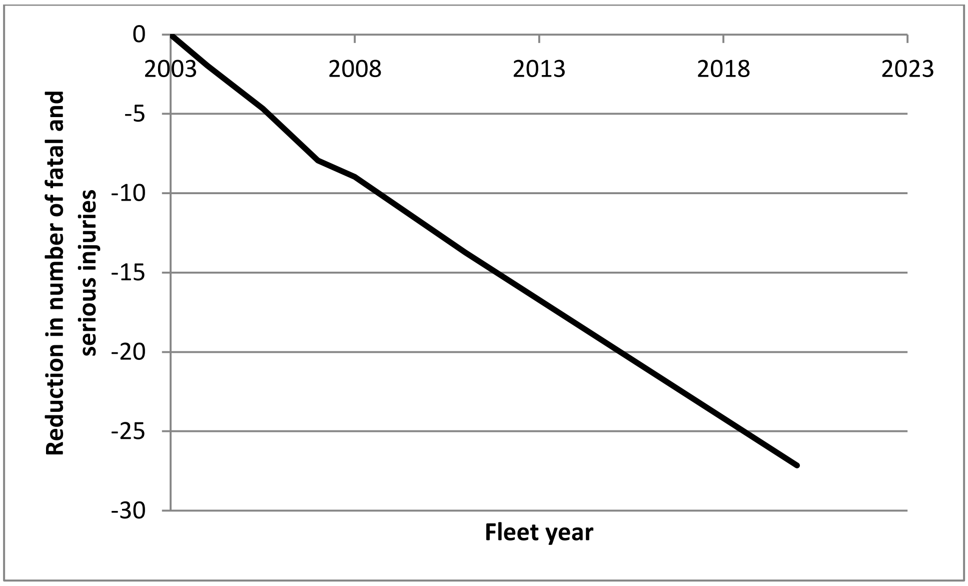



**Figure 13: No further improvement with fleet business as usual scenario: reduction in pedestrian fatal and serious injuries due to fleet changes projected to the year 2020**



## 3.6 AUSTRALIAN PROJECTIONS AND CRASH REDUCTIONS DUE TO FLEET IMPROVEMENTS

As described in Section 2.5.2, projections of Australian fleet aggressivity and fleet composition were made for each market group series for the period 2011 to 2020. Figure 14 and Figure 15 show fleet aggressivity and composition respectively based on past data (1987-2010) and forecasts (2011-2020). Aggressivity and fleet composition (market group proportions) were then combined and summed across market group to determine total fleet pedestrian aggressivity for the period 1987-2020 (Figure 16).

**Figure 14: Australian fleet aggressivity by market group including forecasts 1987-2020**

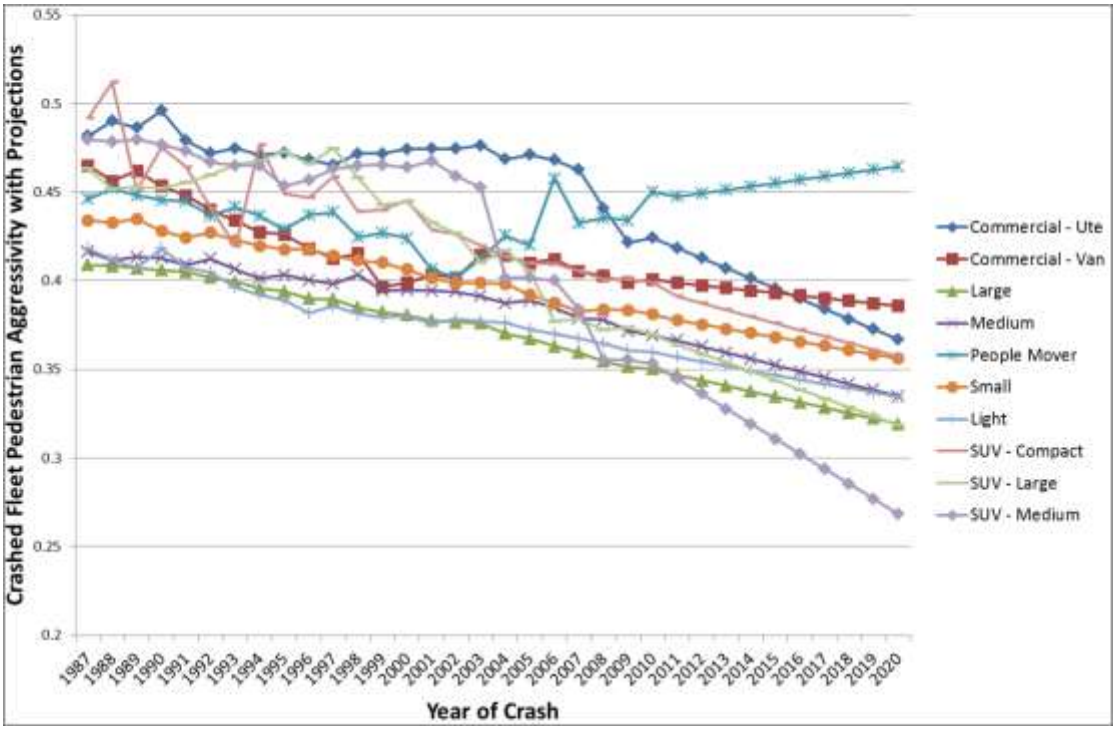


**Figure 15: Australian fleet composition by market group including forecasts 1987-2020**

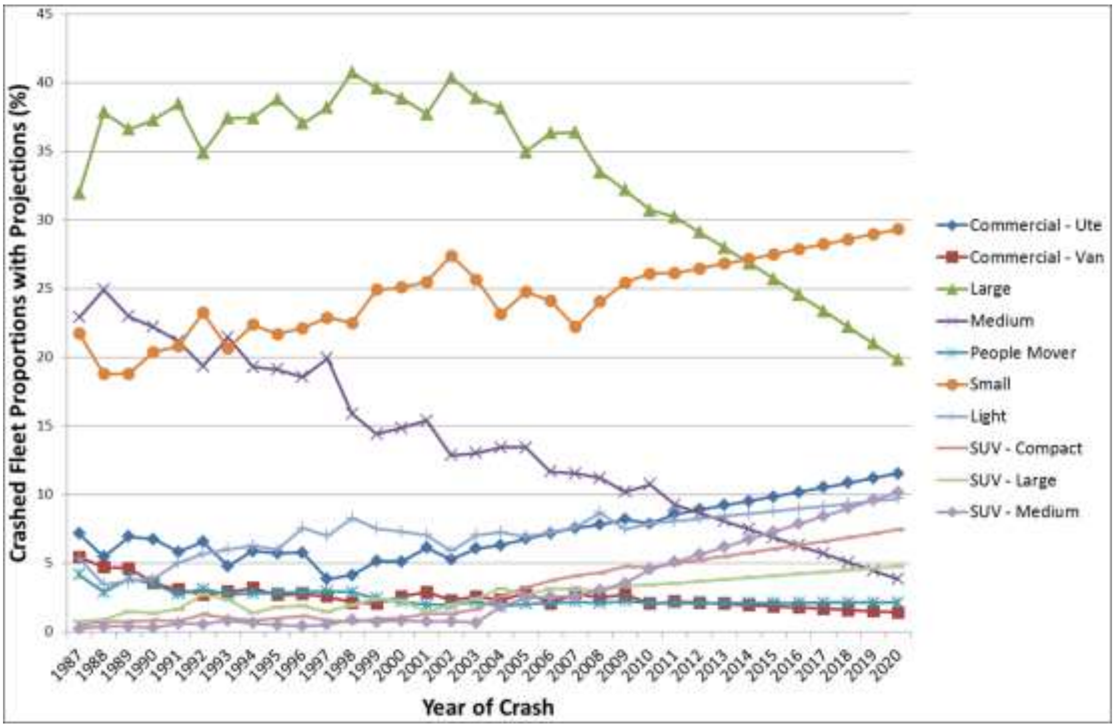
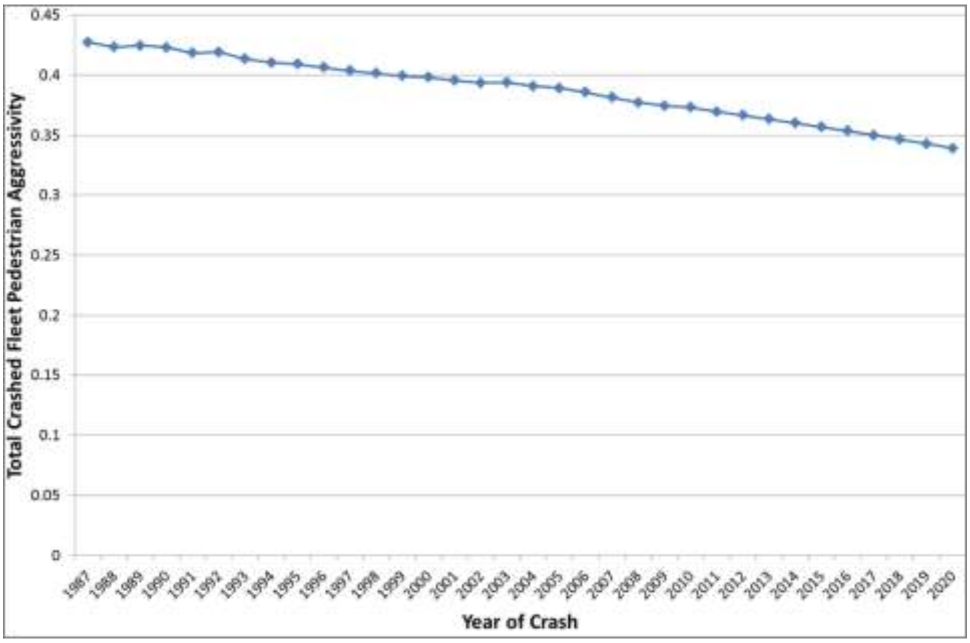



**Figure 16: Total fleet pedestrian aggressivity: observed and projected 1987-2020**




The Australian pedestrian injury dataset consisted of an average 3,125 pedestrian injury crashes per year over the period 2001 to 2010 and was relatively flat. This figure was assumed to remain fixed for the future period of 2011 to 2020 and was combined with the projected (2011-2020) total fleet aggressivity (Figure 16) to estimate the future number of pedestrian killed and serious injury crashes per year. Savings of pedestrian killed and seriously injured crashes post-2010 due to future improvements in pedestrian aggressivity of the Australian fleet were then calculated and are shown in Table 7.

**Table 7: Pedestrian killed and seriously injured crashes saved due to future improvements in pedestrian aggressivity of the Australian fleet 2011-2020**

| Year | KSI crashes | KSI crashes saved |
|---|---|---|
| 2010 | 1199 | - |
| 2011 | 1188 | 11 |
| 2012 | 1178 | 21 |
| 2013 | 1168 | 31 |
| 2014 | 1158 | 42 |
| 2015 | 1147 | 52 |
| 2016 | 1136 | 63 |
| 2017 | 1125 | 74 |
| 2018 | 1114 | 85 |
| 2019 | 1102 | 97 |
| 2020 | 1090 | 109 |

Sensitivity analyses are not presented for the Australian pedestrian serious injury projections. Reflecting the robustness to assumptions of future fleet composition and trends in future vehicle aggressivity found in the New Zealand analysis, the Australian analysis is also robust to changes in these parameters.

## 3.7 POTENTIAL BENEFITS OF EMERGING VEHICLE TECHNOLOGIES

### 3.7.1 New Zealand

As outlined in the Background, above, emerging vehicle technologies have great potential to reduce pedestrian injury further, although precise estimates of these safety benefits are difficult to determine until the technologies become widely used. In the following sub-section, a scenario is described in which a new technology (or combination of technologies) is introduced into all new cars in the New Zealand fleet and then the safety benefits purely of this new technology are estimated. This is a gradual process as these safer (for pedestrians) vehicles percolate through the fleet. For this scenario, the age distribution of the New Zealand fleet as in 2011 is used as a basis and the safety benefit of the new technology is taken to be a 10% reduction in pedestrian injury.

Figure 17 shows as a dashed line the level of penetration of the technology into the fleet as time passes. Only after about 18 years is the technology present in 80% of the vehicle fleet. This means that the 10% injury rate reduction of the technology takes a long time to be realised at the fleet level: the annual rate of pedestrian injuries overall is only reduced by about 8% after 18 years. In aggregate over a 20-year period from the introduction of the technology, 3.8% of all pedestrian injuries would be prevented. It should be noted that the nature of the NZ fleet age distribution does impede the penetration of new technologies. Only 2.3% of the 2011 fleet consisted of new vehicles compared to over 8% that were 15 years old. Fleets that do not import used vehicles would have a much higher proportion that were new and fitted with new technologies.

**Figure 17: Using NZ fleet age distribution in 2011 as a basis, the market penetration of a new technology or technologies introduced to all new vehicles from year=1 onwards; also the relative fleet injury rate associated just with this technology (which yields a 10% injury reduction)**

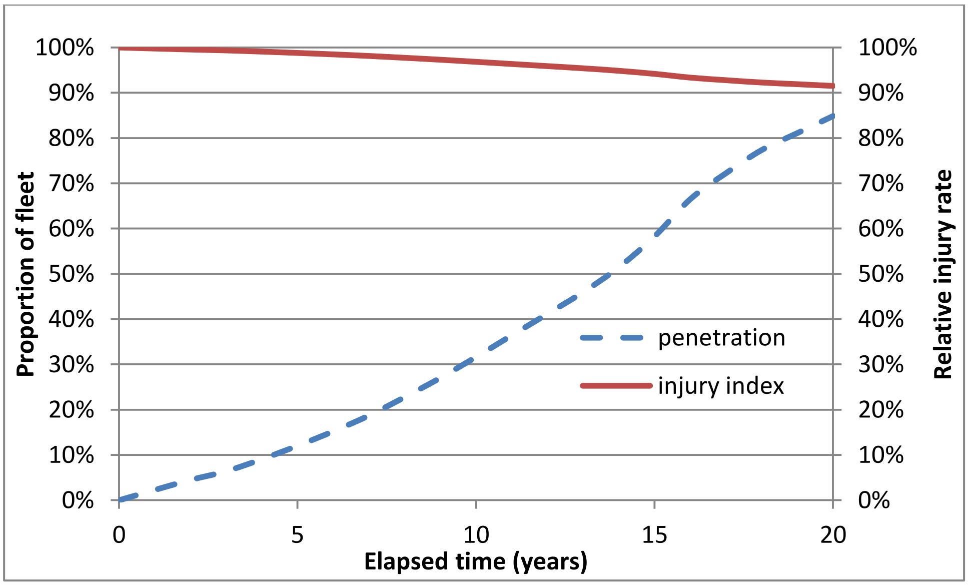



Table 8 shows the total social cost of pedestrian injury in New Zealand over the period 2004 to 2011 according to valuations of injury provided by the Ministry of Transport (2012). The final row of Table 8 shows the average social cost per vehicle over a 20-year period (using the average costs over 2004 to 2011), which can be considered the nominal lifetime of a vehicle. This indicates that in June 2012 prices, a cost of NZ$233 would be justified per vehicle solely as a means to prevent all pedestrian injury. Of course, no vehicle technology currently available is likely to prevent all pedestrian injuries: a technology that prevented 10% of pedestrian injury would only be cost-beneficial if it cost less than 10% of $233, viz., $23.30.

**Table 8: Total number of reported pedestrian casualties (due to cars, vans, SUVs, utility vehicles) along with annual social costs, average totalled across the period, and per vehicle costs (20-year lifetime)**

| Year | No. fatalities | No. hospitalisations | No. minor injuries | Total social costs* |
|---|---|---|---|---|
| 2004 | 38 | 270 | 729 | $268,133,500 |
| 2005 | 31 | 248 | 704 | $232,193,600 |
| 2006 | 44 | 265 | 694 | $288,168,100 |
| 2007 | 45 | 232 | 636 | $277,494,000 |
| 2008 | 31 | 260 | 678 | $236,453,000 |
| 2009 | 31 | 233 | 681 | $225,687,200 |
| 2010 | 35 | 230 | 737 | $240,867,100 |
| 2011 | 31 | 204 | 666 | $213,735,800 |
| Per year average (2004-2011) total social cost | | | | $247,841,538 |
| Social cost per vehicle (assuming 20-year vehicle lifetime) | | | | $233 |

* Social costs in June 2012 prices, $NZ: $3,797,600 per fatality, $401,100 per hospitalised injury, $21,300 per minor (medically treated but not admitted to hospital) injury (Ministry of Transport, 2012)

### 3.7.2 Australia

For Australia, estimates of projected pedestrian killed and seriously injured crash savings due to emerging technologies were made assuming that all new vehicles were fitted with technology that reduced pedestrian death and serious injury by 10%. Firstly, market penetration was estimated using the age distribution of the Australian pedestrian injury dataset fleet as at 2010. Figure 18 shows the level of penetration of the technology into the fleet over time. Compared with New Zealand, where many used vehicles are imported, the Australian fleet is estimated to be penetrated by the new technologies at a faster rate with 61% of the registered fleet fitted with new technologies after 10 years compared with 32% of the fleet after 10 years for New Zealand. The level of fleet penetration was then combined with the assumed 10% reduction to estimate the reduction in the number of pedestrian killed and seriously injured crashes over the period 2011-2020 attributable to the new technologies (Table 9).

**Figure 18: Fleet penetration of a new technology or technologies introduced to all new vehicles based on the Australian pedestrian injury dataset fleet age distribution as at 2010 (year=0)**

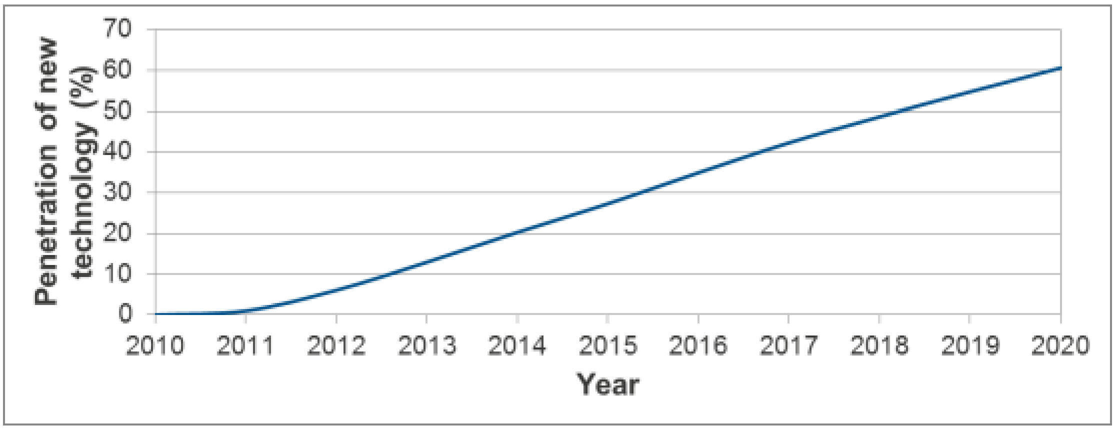



**Table 9: Pedestrian killed and seriously injured crashes saved due to a new technology or technologies introduced to all new vehicles in the Australian fleet 2011-2020**

| Year | Fleet crash reduction (%) | Additional KSI crashes saved |
|---|---|---|
| 2011 | 0.10 | 1 |
| 2012 | 0.61 | 7 |
| 2013 | 1.30 | 15 |
| 2014 | 2.03 | 24 |
| 2015 | 2.74 | 31 |
| 2016 | 3.50 | 40 |
| 2017 | 4.23 | 48 |
| 2018 | 4.87 | 54 |
| 2019 | 5.47 | 60 |
| 2020 | 6.06 | 66 |

Table 10 shows the combined savings in pedestrian killed and seriously injured crashes due to future improvements in pedestrian aggressivity of the Australian fleet (see Table 7) and new technologies introduced to all new vehicles (see Table 9) over the period 2011 to 2020 and the respective social cost savings. The average social cost of a killed and seriously injured crash (AUD $395,775) was calculated by weighting the cost per fatal crash and cost per hospitalised injury crash by the proportion of fatal and serious injury crashes in the Australian pedestrian injury dataset. Table 10 shows that the total social cost savings over the period 2011-2020 amounts to an estimated $368,812,049. The social cost saving per vehicle was then estimated by obtaining new vehicle sales data for Australia from the ABS (catalogue number 9314.0) and forecasting new vehicle sales for the period 2013-2020 using the STAMP software package (Koopman, 2007). The total number of new passenger and SUV vehicles to enter the whole fleet between 2011-2020 was estimated to be 9,311,299. This equates to a social cost saving per vehicle of $39.61. This figure represents a “break even” cost for the new pedestrian injury saving vehicle technology.

**Table 10: Combined savings in pedestrian killed and seriously injured crashes in the Australian fleet due to fleet improvements and new technologies and the respective social cost savings 2011-2020**

| Year | Total crash savings | Social cost savings |
|---|---|---|
| 2011 | 12 | 4,880,524 |
| 2012 | 28 | 11,173,581 |
| 2013 | 46 | 18,337,804 |
| 2014 | 65 | 25,739,353 |
| 2015 | 83 | 33,044,170 |
| 2016 | 103 | 40,648,376 |
| 2017 | 122 | 48,150,447 |
| 2018 | 140 | 55,280,085 |
| 2019 | 157 | 62,283,041 |
| 2020 | 175 | 69,274,668 |
| Total | | $368,812,049 |

Social cost per fatal crash: AUD $2.67 million and per hospitalised injury crash: AUD $266,000 (BITRE, 2009)

# 4 DISCUSSION

This paper has looked at the way that the New Zealand and Australian fleets have been changing over the past nine years with respect to their impact on pedestrian injury severity. By analysing pedestrian injury data from both Australia and New Zealand along with information on the vehicles involved, and the speed limit of the area where the crash occurred, 98% of vehicles in the New Zealand fleet and 90% of the vehicles in the Australian fleet were allocated a pedestrian injury severity rating, which is the probability of fatal or serious injury to the pedestrian given that a crash occurred resulting in injury to the pedestrian. These estimates enabled an average fleet pedestrian injury severity to be estimated, showing improvements in injury outcomes to pedestrians over time. The reduction in the fleet average injury severity risk for pedestrians was estimated to represent an annual saving of at least 14 fatal and serious injuries for the 2011 fleet compared to the 2003 fleet in New Zealand and around 75 in Australia. Over the period 2003-2011, it was estimated that these improvements in pedestrian injury severity ratings saved an aggregate of at least 37 fatal and serious pedestrians injuries in New Zealand and around 340 in Australia.

Next, a model was constructed based on past data to estimate the potential future pedestrian safety impacts of the fleet based on a few scenarios of feasible changes in the fleet. This model for New Zealand fitted past data well, based on three factors: the age distribution of the fleet; the market group composition of the fleet; gradual improvements in vehicle safety for pedestrians over time. Compared to 2003, it was predicted that in the year 2020 there would be between approximately 28 and 32 fewer fatal and serious pedestrian casualties per year under a scenario of business as usual where the fleet generally continued to change in a way as seen in the recent past. If new vehicles ceased to improve as regards pedestrian safety, approximately 27 fatal and serious injuries may be prevented. These estimates indicate that the effects of fleet changes on pedestrian injury are relatively robust to changes in the fleet and much of the safety improvement that is likely to be seen by 2020 will be due to improvements that have already occurred in vehicle safety, which gradually infiltrate the fleet as it ages. A similar model was estimated for Australia based the the market group composition of the fleet and the observed and projected average aggressivity. Vehicle age was not considered explicitly since the age distribution of the Australian vehicle fleet is relatively static. It was estimated that inprovements in average aggressivity of the vehicle fleet likely to be observed in the future would save 170 fatal and serious pedestrian injuries per annum in Australia in 2020 compared to 2003.

A scenario of the introduction of a new technology (or group of technologies) effective in preventing 10% of pedestrian serious injury into all new vehicles from 2011 was tested, using the makeup of the 2011 fleet as the basis to estimate changes in safety over time. No specific technologies were considered in the analysis since, for the vast majority of pedestrian crash avoidance or impact severity mitigation technologies currently available, there have been no formal evaluations to provide a crash reduction estimate to use in the analysis. The annual rate of pedestrian injuries in New Zealand overall was predicted to be reduced by about 8% after 18 years for a technology reducing srious pedestrian injury by 10%. In aggregate over a 20-year period from the introduction of this technology, 3.8% of all pedestrian injuries would be prevented. It should be noted that the nature of the New Zealand fleet age distribution (where the majority of vehicles introduced to the fleet each year are not new vehicles, but are used vehicles imported mainly from Japan) does impede the influence of the safety benefits of new technologies. Comparable reductions in pedestrian serious injury attributable to the new technology in the Australia fleet were a 6.1% annual reduction after 10 years illustrating the faster penetration of the technology due to mainly new cars entering the Australian fleet.

Finally, an attempt was made to estimate the added expense of new technologies that would be merited on a benefit cost basis to prevent pedestrian injury. Assuming a 20-year lifetime for the vehicle (or for the technology), a maximum of NZ$914 was estimated as a per-vehicle break-even cost justified for the prevention of all pedestrian injury at an 8% discount rate. A technology that prevented 10% of pedestrian injury would only justify an additional $91 per vehicle, clearly insuffient to cover the expense of technologies such as the pop-up bonnet or hood, and pedestrian airbags, aimed specifically at preventing or reducing the severity of pedestrian injury. The comparable estimate from the Australian analysis was a break even cost of around $40 per vehicle, the lower value reflecting the use of lower value human capital based injury cost estimates in Australia compared to the willingness to pay based estimates used in New Zealand. These estimates would be correspondingly higher for any technology that achieved greater reductions in serious pedestrian trauma than the 10% assumed. For example, the figures would be double for a technology that reduced serious pedestrian trauma by 20%.

Notwithstanding these results, many technologies, notably Brake Assist Systems, Intelligent Speed Adaptation and Collision Warning Systems have the potential to increase safety for all road users, including pedestrians. The likely wider applicability of the safety effects of these technologies increases the potential safety benefits, and also the acceptability to the motorist. Acceptability is an important criterion for any new technology as it is the motorist who must pay for the additional costs of the technology when purchasing the vehicle. It is also the case that as vehicle safety technologies become more widely installed and manufacturers compete for sales on the basis of safety features included, the effective cost to the motorist for many new technologies can approach zero.

# 5 CONCLUSIONS

- The reduction in the fleet average injury severity risk for pedestrians was estimated to represent an annual fatal and serious injury saving of at least 14 in New Zealand and 75 in Australia for the 2011 fleet compared to the 2003 fleet. Over the period studied, from 2003-2011, it was estimated that these improvements in pedestrian injury severity ratings saved an aggregate at least 37 fatal and serious injuries in New Zealand and 340 in Australia.

- If these improvements continue with expected trends, compared to 2003 the 2020 fleet will have safety characteristics that will save an estimated 28-32 fatal or serious pedestrian injuries per year in New Zealand and 170 in Australia. These injury savings will be slightly lower if past trends in improving safety do not continue into the future.

- Using the characteristics of the 2011 fleet as a basis, the safety effects of a technology assumed to prevent 10% of pedestrian injuries was modelled. After an 18-year period from the introduction of this technology to all new vehicles, 8% of all pedestrian injuries were estimated to be prevented in New Zealand per annum. The comparable figure in Australia was 6.1% savings per annum after 10 years reflecting the faster renewal of the Australian fleet. The penetration of emerging safety technologies into the New Zealand fleet is impeded by the current dominance of used imported vehicles from Japan.

- Some analysis was carried out of the expense justified by an emerging technology to prevent pedestrian injury. A technology that prevented only 10% of pedestrian injury, realistic of typical technology effectiveness, would only justify an additional $91 per vehicle in New Zealand and $40 per vehicle in Australia. This is likely to be insuffient to cover the expense of technologies such as the pop-up bonnet or hood, and pedestrian airbags, aimed specifically at preventing or reducing the severity of pedestrian injury.

- Nevertheless, many technologies, notably Brake Assist Systems, Intelligent Speed Adaptation and Collision Warning Systems have the potential to increase safety for *all* road users, including pedestrians. The likely wider applicability of the safety effects of these technologies increases the potential safety benefits, and also the acceptability to the motorist, who must pay for the additional costs of the technology when purchasing the vehicle.

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