# MONASH University
## Accident Research Centre

# PROJECTING EFFECTS OF IMPROVEMENTS IN PASSIVE SAFETY OF THE NEW ZEALAND LIGHT VEHICLE FLEET TO 2010

by

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**Project Sponsored By**

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## REPORT DOCUMENTATION PAGE

**Abstract:**

In the year 2000, NZ road safety targets were set for a reduction in social cost of 15.5% associated with improvements in crashworthiness, which is a measure of the occupant protection provided by vehicles in the light vehicle fleet. Since that document was produced, new estimates of crashworthiness have become available allowing a more accurate projection. This paper describes a methodology for projecting changes in casualty rates associated with passive safety features, based primarily on projections of the existing crashworthiness trends and thereafter including the effects of two potential interventions: restrictions on the importation of cars into New Zealand and restriction of government fleet vehicles to those with superior crashworthiness. Compared to the quite large social cost reduction of about 22% expected to occur largely due to improvements in the crashworthiness of the fleet over time, these additional interventions were predicted to yield fairly modest savings.

# EXECUTIVE SUMMARY

The New Zealand National Road Safety Committee produced a road safety strategy for 2010 (National Road Safety Committee, 2000) that included a target for casualty reductions associated with improvements to built-in safety features (providing *passive* or *secondary* safety) of light passenger vehicles (that is, passenger vehicles of Gross Vehicle Mass 3500 kg or less). The degree of passive safety provided by a vehicle was expressed in terms of its crashworthiness, which is the result of statistical analyses of police-reported crash data. At that time the only crashworthiness figures available were those for Australia. The target set in 2000 was a reduction in baseline (year 2000) social cost of 15.5%.

Since 2000, new estimates have become available via Monash University's study of crashworthiness of the New Zealand light-vehicle fleet (Newstead and Watson, 2005) and five years have passed, allowing a more accurate assessment of projected savings than could have been made in 2000. This document describes modelling procedures and projected changes in casualty rates, based primarily on projections of the existing crashworthiness trends and thereafter including the predicted effects on social cost of two potential interventions. These are specifically:

- From the year 2006, no imported used light vehicle to be more than 7 years old.
- From 2006, only light vehicles that are at least 4-star rated to be allowed to enter the NZ Government fleet.

In order to project changes in passive safety, two effects were modelled simultaneously: changes with time in the age composition of the light-vehicle fleet and changes in crashworthiness associated with vehicle age. The methodology was similar to that used in 2000 to produce the 2010 targets (National Road Safety Committee, 2000) but the crashworthiness figures for New Zealand were now available and could be used instead of those from Australia. The projected effects of the two potential interventions were evaluated according to their influence on the fleet composition via the importation of vehicles and the scrapping of (generally older) vehicles. To account for uncertain market effects, the effects of limiting on the age of imported used vehicles was modelled under two contrasting scenarios to provide likely upper and lower bounds for its impact on passive safety.

In Australia technical improvements flow into the fleet more rapidly than in New Zealand as used imports do not enter the fleet in significant numbers. Since vehicles are new when they enter the fleet and since they are required to meet the Australian Design Rules (ADRs) they incorporate recent advancements in technology. As a result, when the target-setting exercise was first carried out, improvements in crashworthiness had already occurred in Australia at a time where New Zealand was still lagging behind. Using the more accurate crashworthiness results now available for the New Zealand fleet, the 2010 target of a reduction of 15.5% in total social cost appears likely to be exceeded by a large margin. If trends in fleet constitution and crashworthiness continue, there is predicted to be an improvement (compared to the year 2000) of about 30% in light vehicle casualties and 22% reduction in total social cost.

Compared to this large social cost reduction, the two potential interventions considered are predicted to yield only modest savings. If age restrictions were imposed on imported vehicles, allowing only those manufactured seven years or less prior to their sale in NZ, it is

predicted that, at best, there may be a 4% saving in overall social cost in the year 2010 compared to the "business as usual" approach. Not considered in this report was the potential for motorcycle ownership to increase in response to restrictions on the availability of used vehicles in the lower price ranges. Such an eventuality could have a serious impact on road trauma. Also not considered was the availability of used vehicles in the age range of seven years or fewer since manufacture. If imported used vehicles are not sufficient to fulfil demand, there may be an adverse impact on fleet crashworthiness as drivers retain older vehicles that would otherwise have been scrapped. The other scenario, in which all new government fleet vehicles have the best crashworthiness and aggressivity within the given market group, was limited in its effect because of the relatively small NZ government vehicle fleet. Only a 0.1% saving in overall social cost was predicted as the most optimistic result of this scenario.

# ACKNOWLEDGMENTS

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# PROJECTING EFFECTS OF IMPROVEMENTS IN PASSIVE SAFETY OF THE NEW ZEALAND LIGHT VEHICLE FLEET TO 2010

## 1. BACKGROUND

### 1.1 NZ light vehicle fleet targets for 2010

The New Zealand National Road Safety Committee produced a road safety strategy for 2010 (National Road Safety Committee, 2000) that included a target for casualty reductions associated with improvements to built-in safety features (providing *passive* or *secondary* safety) of light passenger vehicles (that is, passenger vehicles of Gross Vehicle Mass 3500 kg or less). The degree of passive safety provided by a vehicle was expressed in terms of its crashworthiness, which is the result of statistical analyses of police-reported crash data. At that time the only crashworthiness figures available were those for Australia. The target set in 2000 was a reduction in baseline (year 2000) social cost of 15.5%.

Since that document was produced, new estimates have become available via Monash University's study of crashworthiness of the New Zealand light vehicle fleet (Newstead and Watson, 2005) and five years have passed, allowing a more accurate assessment than could have been made in 2000 of projected savings.

This document describes modelling procedures and projected changes in casualty rates, based primarily on projections of the existing crashworthiness trends and thereafter including the predicted effects on social cost of two potential interventions. These are specifically:
- From the year 2006, no imported used light vehicle to be more than 7 years old.
- From 2006, only light vehicles that are at least 4-star rated to be allowed to enter the NZ Government fleet.

### 1.2 Crashworthiness

The crashworthiness rating (CWR) used in this report is a measure of the risk of fatal or serious injury to a driver of a car involved in crash with another vehicle whose driver is injured (Newstead and Watson, 2005).

Note that this differs from crashworthiness measures used in countries such as Australia where non-injury crashes are available in most states' official databases, meaning that crashworthiness can be defined as the risk of driver serious injury (or death) given that the driver is involved in a *tow-away* crash (e.g., Cameron et al., 1994). Nevertheless, the New Zealand and Australian crashworthiness measures are expected to vary proportionately in the same fashion (Newstead and Watson, 2005). In other words, for any comparison between two vehicles, A and B, an *x*% difference in rating for vehicle A compared to vehicle B is expected to be estimated by both rating methods.

The New Car Assessment Programme (NCAP) tests popular models of cars in crash tests of various configurations, providing ratings of safety performance in terms of stars (the more stars, the better). The relationship between the NCAP star ratings and real-life performance has been

investigated by a few studies. Lie and Tingvall (2002) estimated that in car-to-car collisions, cars with three to four stars were approximately 30% safer than cars with either two stars or no NCAP test available.

## 1.3    History of the NZ light vehicle fleet

For most of the twentieth century, starting with the General Motors assembly plant in 1926, New Zealand had a local vehicle industry. In the late 1980s, however, the face of the industry changed dramatically as a result of the progressive removal of import controls from all automotive products and reduction of tariffs on both vehicles and components. There were a number of motivating factors for the Government decision to allow used vehicles to be imported into New Zealand. One was to provide a wider source of relatively new and relatively affordable vehicles for New Zealand consumers (which in turn put pressure on new vehicle prices). The need for this was highlighted by a trend towards an ageing vehicle fleet in New Zealand at that time. Another motivation for the used import program was to attempt to reduce the number of motorcycles in the New Zealand fleet. New motorcycle registrations had been at a high level during the 1970s and early 1980s and they were known to be a less safe means of transport than a car.

The 1990s saw a boom in the sale of used import vehicles in New Zealand along with a corresponding decline in the sales of new vehicles. Figures quoted in TRC (2002) show the percentage of used imports in annual vehicle registrations from 1960 to 1986 was generally much less than 10%. The period from 1987 onwards saw a sharp rise in this percentage and by 2002 around 68% of all vehicle registrations in a year were imported used vehicles. Annual registrations of vehicles sold new in New Zealand have shown a corresponding decline over the period from around 90,000 units in the early 1980s to around 60,000 units by the early 2000s. Under these economic constraints, by the late 1990s the local vehicle assembly industry had ceased operation.

The increase in the percentage of used import vehicle registrations in New Zealand is also reflected in crash data summaries such as LTSA (2004). Illustrating this point, Figure 1 plots the proportion of used import vehicles crashing in New Zealand over the period 1991 to 2002 by year of first registration in New Zealand, derived from the data analysed in that study. The proportion of crashed vehicles by year of first registration in New Zealand that are used imports generally follows the trends expected from the registration statistics with rapid growth between 1987 and 2002.
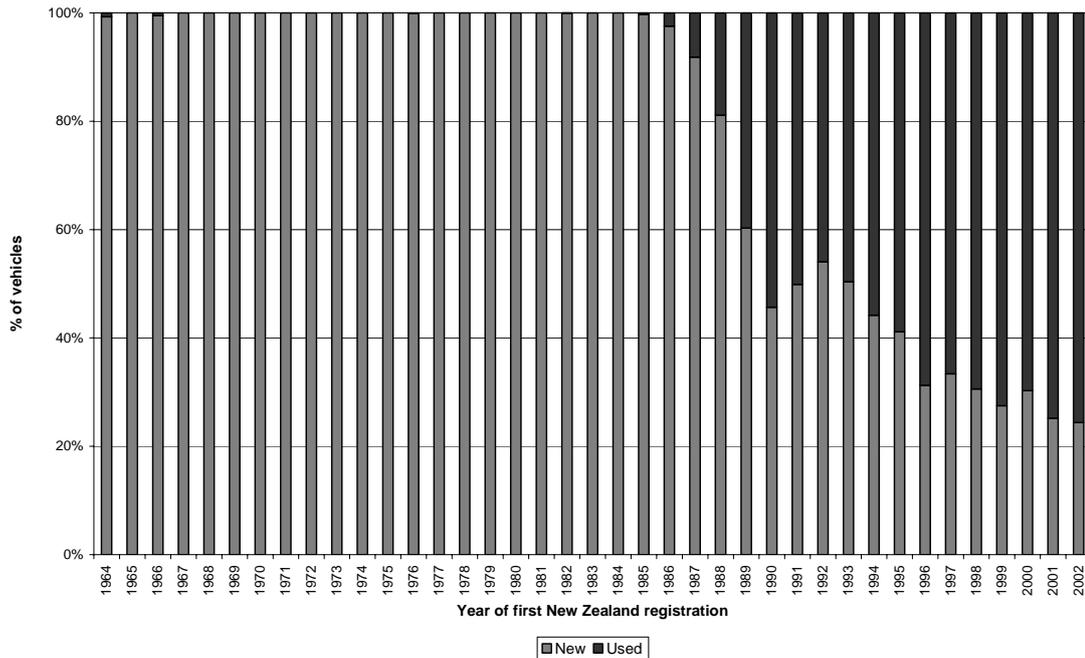
**Figure 1: Percentage of vehicles sold new in New Zealand and imported used by year of first registration in New Zealand in the 1991-2002 crash data.**

The vast majority of the used light passenger vehicles imported into New Zealand come from Japan. Indeed, around 75-80% of all new registrations of both new and used vehicles in New Zealand are Japanese vehicles with Australian vehicles the next most prevalent at around 8% of new vehicle registrations.

Like most countries, New Zealand has a system of regulations to govern the safety of vehicles on the road in New Zealand. The earliest of these were the Traffic Regulations 1936 (TR36), updated in 1954 (TR54) and 1976 (TR76). For many years, the general focus of the Traffic Regulations was to set requirements for vehicles built in New Zealand. However, a separate set of regulations governing vehicle standards was developed in order to align New Zealand legislation with that of standard-setting bodies in safety-conscious jurisdictions overseas from which the vehicles were sourced, namely Australia, Japan, UN/ECE and the USA. These Transport (Vehicle Standards) Regulations (1990) (VSRs) set out the technical standards with which motor vehicles must comply in order to be registered in New Zealand.

Over the period since 1990, the vehicle standards policy in New Zealand has been clarified by Government in consultation with the vehicle industry using the consultative rule-making procedure, and today the VSRs have been replaced by Land Transport Rules covering standards and safety requirements. In addition, the important Compliance Rule sets out requirements for inspection and certification of vehicles to ensure they meet the safety requirements at import and when on the road in New Zealand. Details of the vehicle standards requirements and legislation are available on the Land Transport New Zealand web site (www.landtransport.govt.nz)

## 1.4    Social cost

Social cost savings associated with the projected changes in the secondary safety of the light vehicle fleet were estimated using the average social cost per reported crash. The social costs of a road crash and the associated injuries include a number of different elements: loss of life and life quality; loss of output due to temporary incapacitation; medical costs; legal costs; property damage costs. The average value of a loss of life is estimated by the amount of money that the members of the New Zealand population would be willing to pay for a safety improvement that results in the expected avoidance of one premature death. It is a measure of the pain, suffering and loss of life component of the social cost (Ministry of Transport, 2005).These valuations are regularly inflation adjusted. However, the estimates of social cost savings in this report are quite robust to such adjustments as they are expressed in terms of *proportional* savings, not in terms of absolute values. The social cost saving estimates in this study are based on savings by crash severity type multiplied by the average social cost in June 2004 prices, accounting for the proportion of social cost attributable to light vehicle crashes according to crash data for the 2000-2002 period. The total social cost of road crashes involving injury in 2004 was estimated to be $3,103 million (Ministry of Transport, 2005).

## 2. DATA

### 2.1 Injury data

The crash data analysed in this study consist of police-reported injury crashes. The ages of the vehicles used for the analysis are as recorded in the Traffic Crash Report.

In the analysis that follows, it is assumed that the distribution by vehicle age of vehicles involved in all injury crashes is similar to the distribution of vehicles involved in serious and fatal injuries. The reason for using vehicles involved in all injury crashes is to make the most of the added statistical power available from dealing with larger numbers of crashed vehicles. The following graph (Figure 2) illustrates that both distributions are similar and that this assumption is therefore tenable.
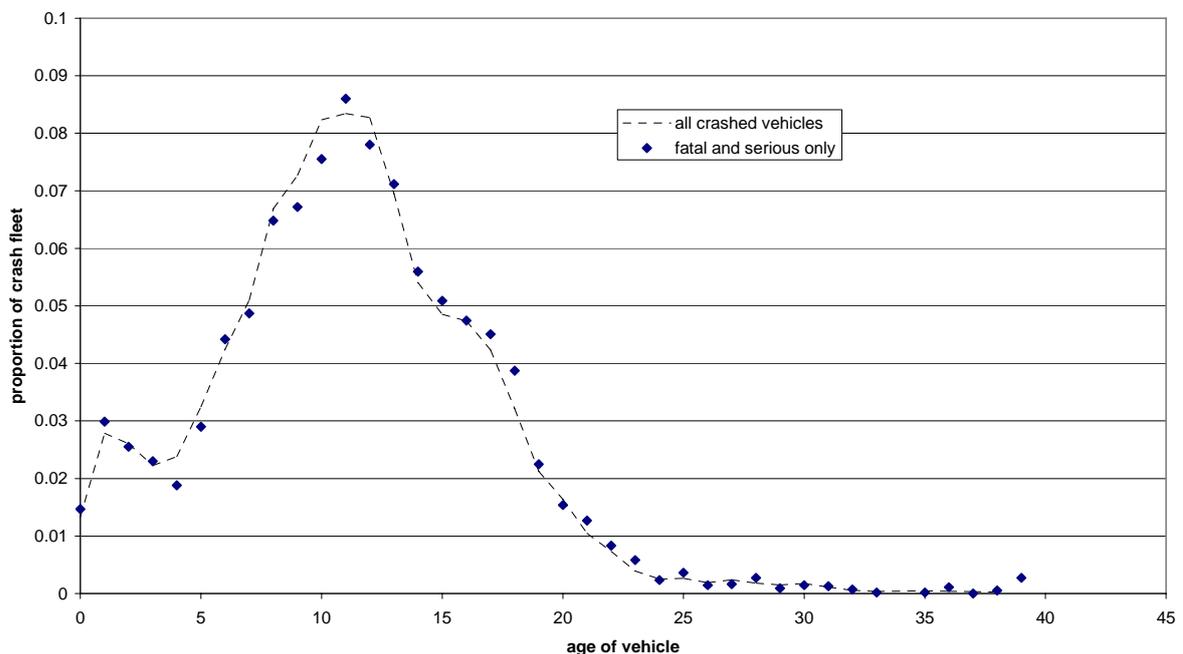


**Figure 2: Distribution of crashed vehicles for the years 2001 and 2002, with all injury crashes as the dotted line and serious and fatal crashes as diamonds.**

### 2.2 Registered vehicle fleet or crash fleet?

A decision needed to be made as to whether to make inferences about the crash effects of changes in the fleet of registered vehicles or to deal directly with the shape of the crashed fleet and then decide what changes amongst registered vehicles would lead to such shapes.

Figure 3 (from National Road Safety Committee, 2000) shows a comparison of the distributions of the crash fleet and the registered vehicle fleet for the year 1997. This shows that the crash fleet and the on-road fleet are not equivalent: older vehicles are relatively overrepresented in the crash fleet and younger vehicles underrepresented. The relationship between these two distributions can be analysed further by looking at relative risks per licensed vehicle of injury crash involvement (Figure 4). This shows that risk (calculated by dividing the numbers represented by the dotted line of Figure 3 by those represented by the solid line) increases approximately exponentially (shown by the fitted line) with increasing age of the vehicle.

Factors influencing risk of crash involvement include vehicle attributes, amount and type of exposure as well as driver effects on risk (Keall and Frith, 2004). Also shown in Figure 4 is the formula for the fitted regression line to the risk per licensed vehicle against vehicle age, together with its $R^2$ of 0.721, showing a good fit.

Although Figure 3 clearly shows that the distributions of the on-road vehicle fleet and the crashed vehicle fleet are different, they nevertheless have a close to functional relationship (as shown by the fitted curve[1] of Figure 4) that allows us to use the crash fleet distribution in predictive models and then make statements about the underlying on-road fleet along the following general lines: for a given proportion of older vehicles in the crash fleet, there will be a relatively smaller proportion of older registered (on-road) vehicles; for a given proportion of newer vehicles in the crash fleet, there will be a relatively larger proportion of newer registered vehicles. Given these considerations, it was clearly simpler to deal with projections regarding the crash fleet distribution.
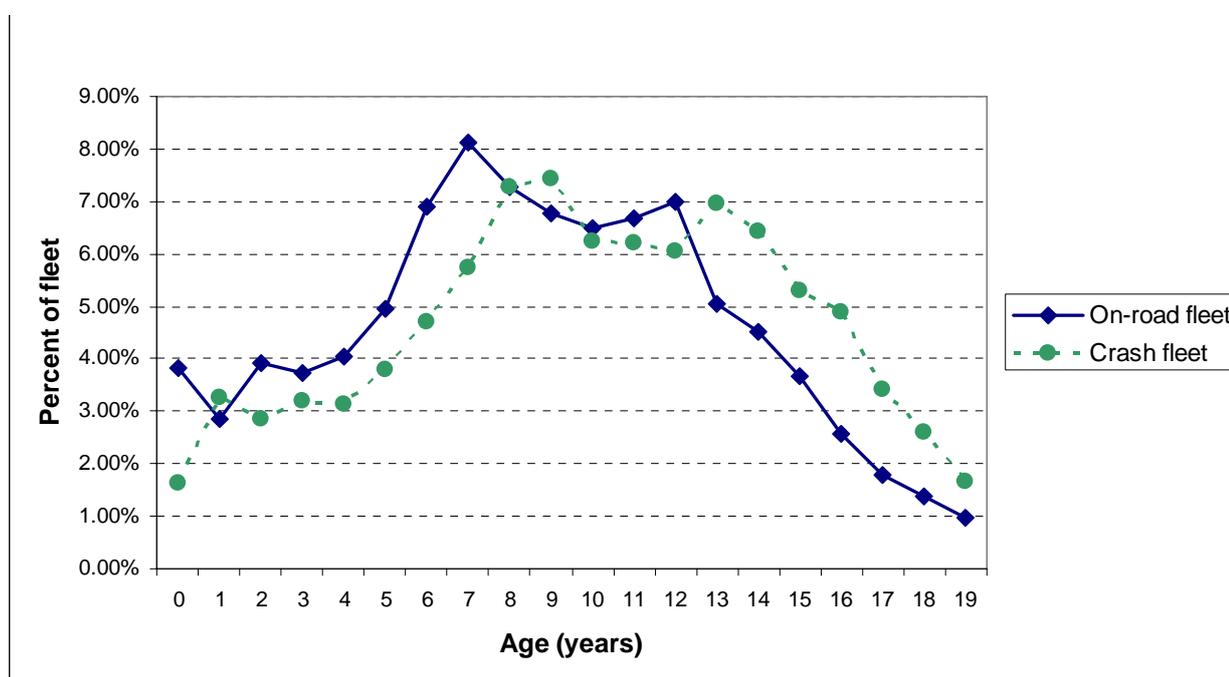


**Figure 3: Comparison of 1997 light vehicle on-road and crash fleet age profiles**

The relative crashworthiness rating (CWR) of the NZ and Australian fleets is plotted in Figure 5 (data from Newstead and Watson, 2005). NZ crashworthiness appears to follows an exponential curve against vehicle age from 1980 to 2002 according to the fitted curve shown, which has an $R^2$ of 0.89. This means that the CWR of the fleet can be projected quite simply into the future using this trend. This projection is used as the most likely scenario for the future, but the possibility that crashworthiness may have plateaued is also considered. Figure 5 shows crashworthiness represented as levels indexed to the average 1964 vehicle for the respective country. The slower improvement in crashworthiness (indicating more slowly improving outcomes for the crash-involved driver) from a lower 1980 level for Australia is likely to be associated with many safety benefits being introduced to the Australian fleet several years before they influenced the NZ fleet (Newstead and Watson, 2005). In Australia technical

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[1] The data to which the exponential curve is fitted show a systematic cyclical pattern around the fitted line. However, the fitted line clearly presents a reasonable estimate of the relationship between age of the vehicle and relative risk, which is what is important for this study.

improvements flow into the fleet more rapidly than in New Zealand as used imports do not enter the fleet in significant numbers. Since vehicles are new when they enter the fleet and since they are required to meet the Australian Design Rules (ADRs) they incorporate recent advancements in technology. As a result, when the target-setting exercise was first carried out, improvements in crashworthiness had already occurred in Australia at a time where New Zealand was still lagging behind. From the early 1980s to the early 2000s years of manufacture, NZ CWR has improved by about 50%, equivalent to the total improvement seen in Australian vehicles from 1964 to 2002 (ibid). Only the Australian CWRs were available when the initial projections of the NZ light vehicle fleet safety were made in the year 2000 (as published in National Road Safety Committee, 2000) in order to set the New Zealand 2010 light vehicle safety targets.



The fitted curve is labelled $y = 0.5652e^{0.0586x}$ with $R^2 = 0.721$.
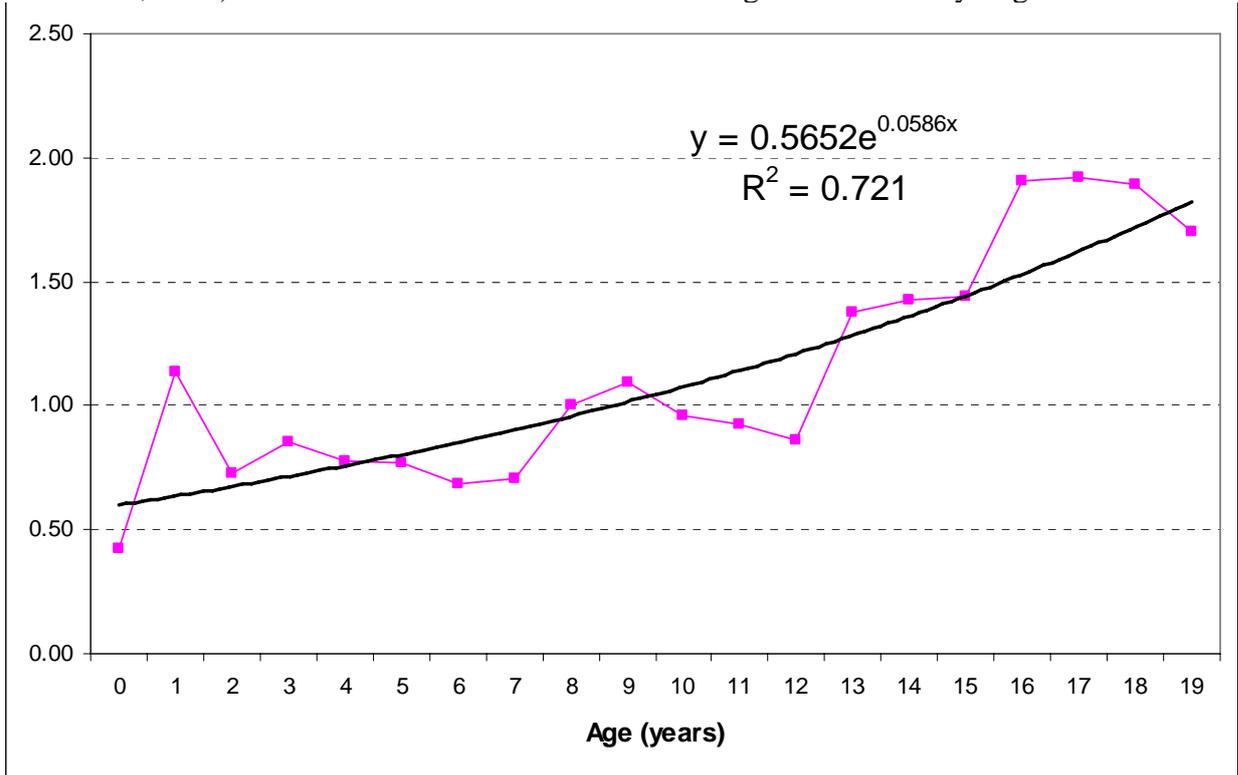
**Figure 4: Risk per vehicle according to 1997 on-road (licensed vehicle) and crash fleet age profiles together with fitted exponential curve against age of vehicle, relative to overall fleet average risk per vehicle.**
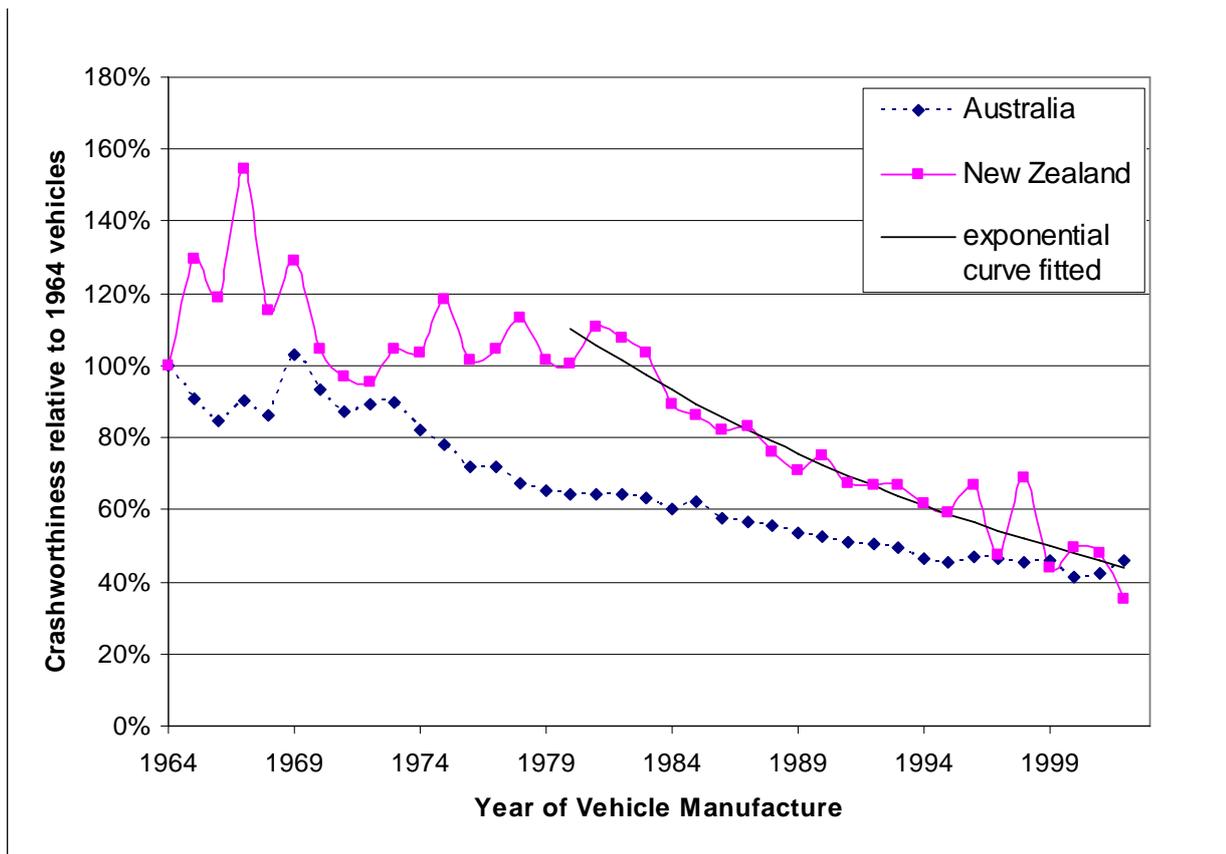
**Figure 5: Crashworthiness of the NZ and Australian vehicle fleets relative to 1964 vehicles by year of manufacture, with exponential trend line fitted to NZ data from 1980 to 2002 (estimates from Newstead and Watson, 2005).**

# 4. ANALYSIS

## 4.1 Predicting the shape of the crash fleet in 2010

Various methods can be used to predict the shape of the distribution of the crash fleet. The method chosen analysed the changes happening over time in the crash fleet and estimated the shape of the distribution by projecting these patterns of change into the future. Figure 6 shows seven distributions of the crash fleet by vehicle age for pairs of years from 1991 to 2004. The distribution appears to be changing over time, becoming older on average with proportionately fewer new vehicles entering the fleet, although many used vehicles are imported into the fleet.
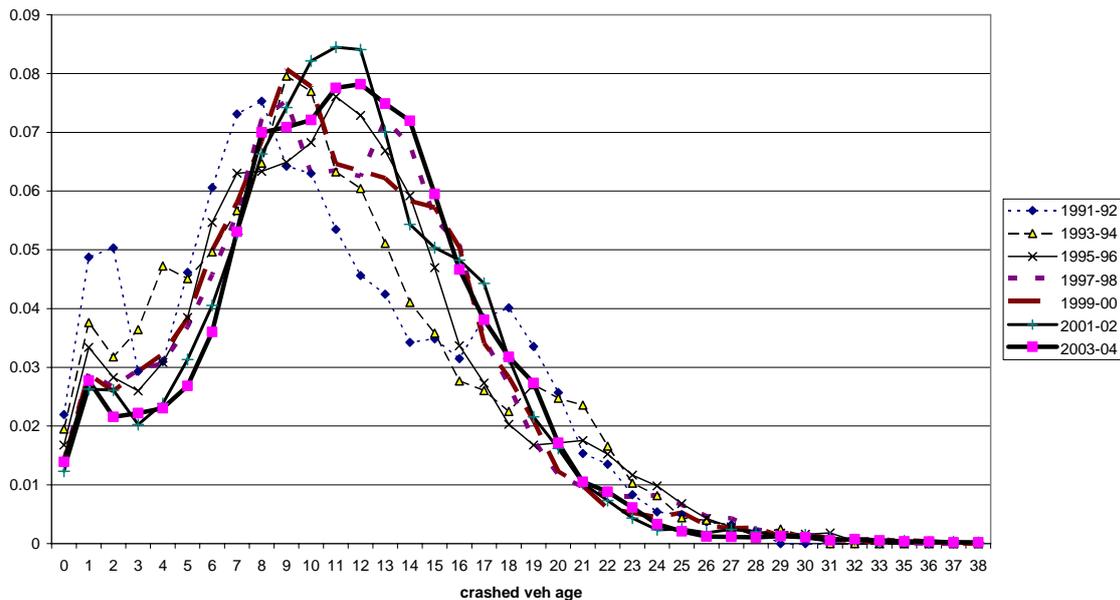


**Figure 6: Distributions of crashed vehicles by vehicle age and years of crash**

By aggregating these distributions across age intervals that appeared to best summarise the changes from year-to-year, simplified curves shown in Figure 8 were produced. Projected distributions for 2005/2006, 2007/2008 and 2009/2010 were derived by projecting the patterns of change into the future. This was achieved by simple linear regressions of the proportion of crashed vehicles within vehicle age ranges against year of crash, shown in Figure 7. The trend with time shown by both Figures 7 and 8 is for fewer new vehicles, more vehicles aged 9-18 years, but proportionately fewer vehicles older than 18 years. As an example of the interpretation of the data shown in Figure 7, the top left hand point shows that vehicles 8 years old and younger made up approximately 44% of the crash fleet in the years 1991/92. By 2003/2004, only about 29% of the crash fleet were these newer vehicles. This is an unusual way for a population to change over time and is due to the large number of used imported vehicles that enter the fleet, boosting the proportions in the 9-18-year-old age bracket. For the equations of the trend lines shown in Figure 7, the variable "$x$" takes the value 1 for 1991/92, the value 2 for 1993/94 and so forth.

**Figure 7: Proportion of crash fleet in given year of crash (horizontal axis) for age ranges of crashed vehicles**



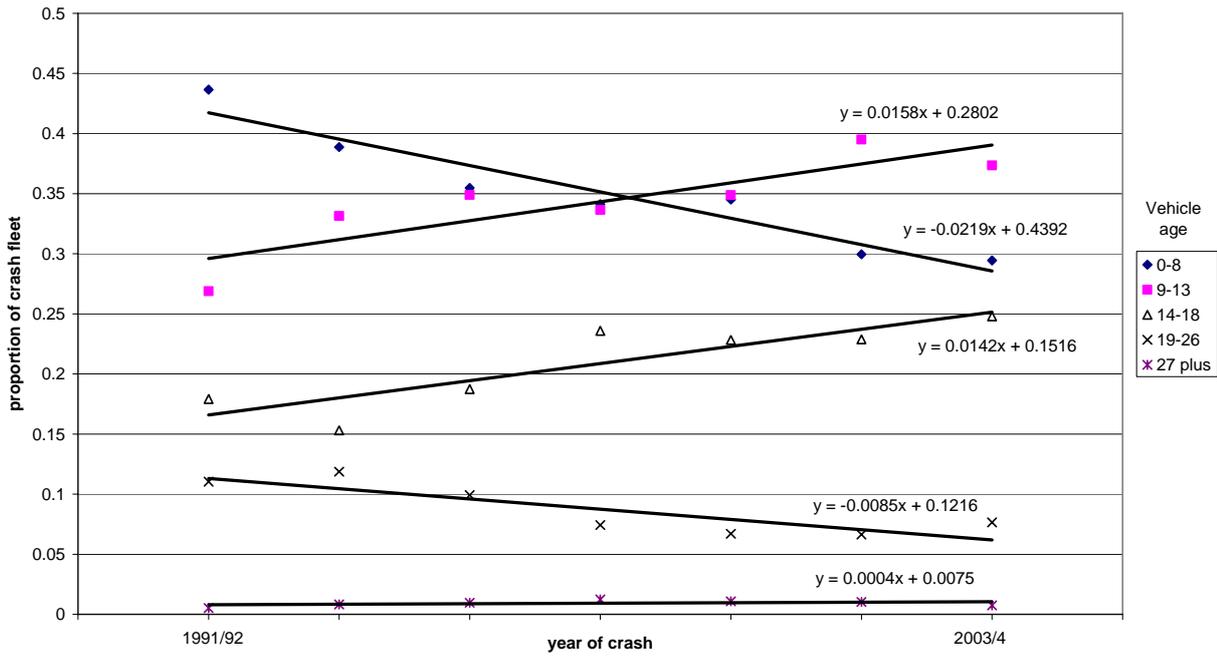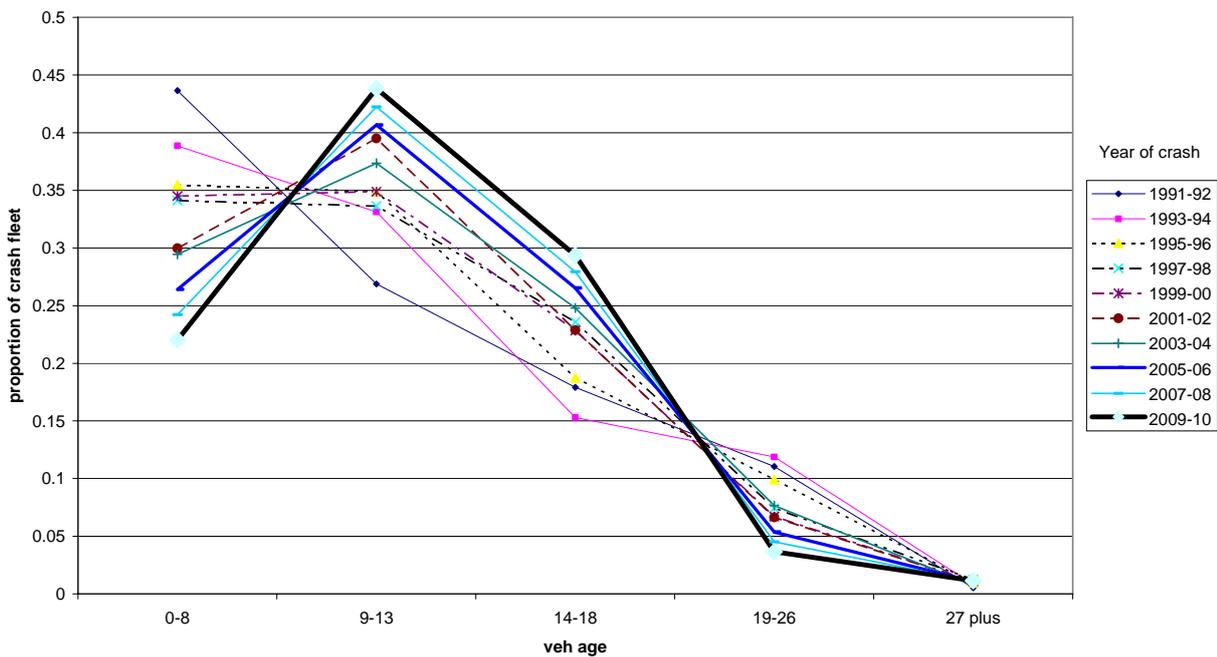**Figure 8: Simplified distribution of crash fleet by vehicle age and years of crash**
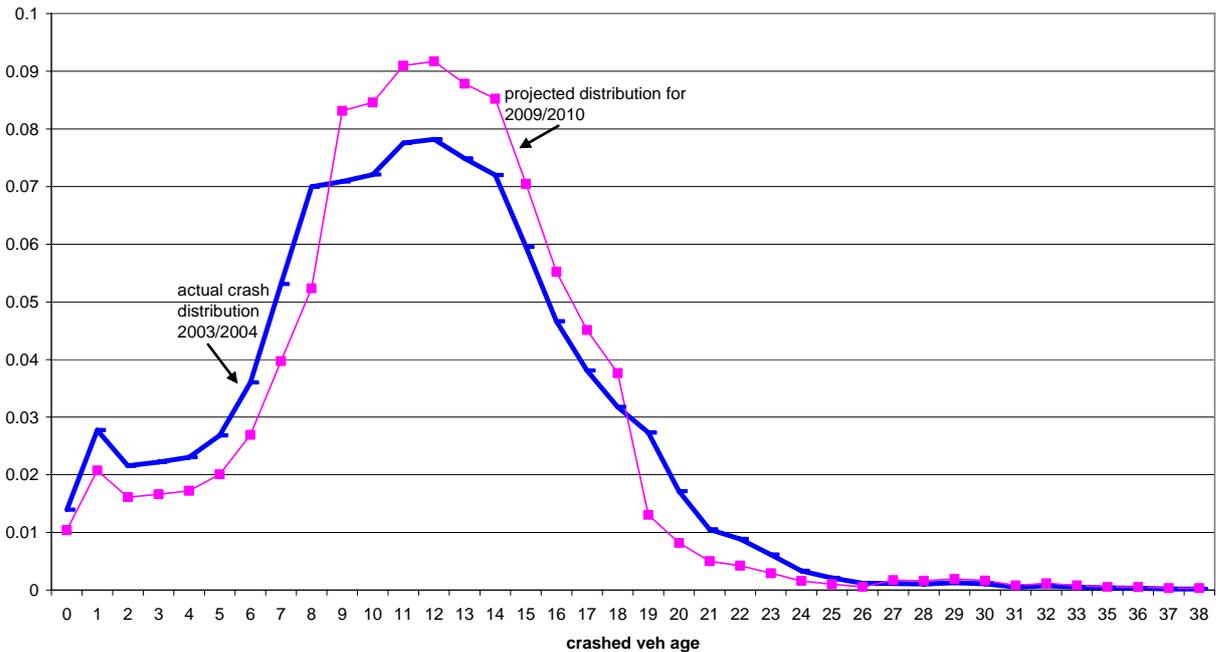
**Figure 9: Distribution of crashed vehicles by vehicle age for 2003/2004 and projected distribution for 2009/2010**

When these projected changes were applied to the most recent available distribution of the crash fleet (2003/2004), the crash fleet for 2009/2010 could be predicted, as shown in Figure 9. Also shown is the distribution for 2003/2004 used as a basis to derive the 2009/2010 distribution, in combination with the fitted lines of Figure 7. As shown in the Results section, below (Table 1), the shape of the projected crash fleet distribution has a relatively minor effect on projected injuries compared to the influence of diminishing CWR over time. This is really an artefact of the shape of CWR curve against vehicle age, which takes the approximate form of an exponential curve (see Figure 5). A mathematical explanation of the lack of strong distributional effects is given in Section 4.2. It is important to note the reduction in the proportion of older vehicles in the fleet shown in Figures 8 and 9. This shows that the used import programme may be encouraging (or at least supporting) purchasing patterns leading to a reduced lifetime for vehicles in New Zealand.

## 4.2   Combining crashworthiness estimates with crash fleet projections

The following describes how changes in injury rates were estimated. The crashworthiness estimates can be combined with estimated fleet distributions in the following way:

1. Take *NA* drivers of crash-involved vehicles in time period *A* that have crashworthiness *CWR(A)*. Then, by the definition of crashworthiness in Section 1.2, the expected number of these drivers who will be killed or seriously injured will be: $CWR(A) \times NA$

2. Suppose that in ten years time, in period *B*, the vehicles of these drivers are replaced by vehicles of the same age (years since manufacture) with better crashworthiness *CWR(B)* (better protection for the driver in the event of a crash).

3. Then a certain proportion of the *NA* crashing drivers who would have been seriously injured or killed will be better protected by their vehicles and will not be injured or will have minor injuries. It is estimated that $CWR(B) \times NA$ will still be killed or seriously injured.

4. There may also be changes in the distribution of the crash fleet by age of vehicle, such that for vehicle age $i$ in time period $A$, there are $NA_i$ crashed vehicles in time period $A$, but a different number, $NB_i$ in period $B$, with vehicle age $i$ (years since manufacture as at time $B$). Of course, the years of manufacture will differ for these two groups of vehicles. For example, if $B$ is the year 2010 and $A$ is the year 2000, then for $i=10$, $NB_i$ will refer to vehicles manufactured in the year 2000 and $NA_i$ to vehicles manufactured in 1990.

5. Then the change in the serious and fatal injury rate of drivers due to the combined effect of the change in the crash fleet distribution and the crashworthiness of the fleet can be estimated by $\dfrac{\sum\limits_{i} CWR(B)_i \times NB_i}{\sum\limits_{i} CWR(A)_i \times NA_i}$, which is the ratio of the total expected number of fatal and seriously injured drivers in time $B$ relative to the expected number in time $A$.

Although the crashworthiness measures refer to driver risk of injury, it is reasonable to assume that other occupants of a given vehicle will share many of the benefits of the safety features that protect the driver (Evans, 2004). Therefore, it is assumed that improvements in crashworthiness will proportionally affect the number of vehicle occupants who are injured in crashes in a similar way to the number of drivers injured in crashes. Further, it is likely that safety features that reduce the occurrence or severity of serious injuries will have at least the same beneficial effect on the occurrence of less serious injuries[2] (ibid). As minor injuries in light vehicle crashes are a relatively small proportion (about 12%) of total social cost (Jones, 2005), there would be relatively little bias in the estimates presented here if the assumption were not justified.

These assumptions provide the rationale for deducing changes in injury rates resulting from estimated changes in serious injury rates to drivers (noting that the crashworthiness ratings refer to probabilities of serious or fatal injuries to the driver).

Mathematically, as long as $NA_i \cong NB_i \ \forall i$, the shape of the distribution of the crash fleet has almost no impact on the estimated saving. As mentioned in Section 4.1 above, this is because the shape of CWR curve against vehicle age takes the approximate form of an exponential curve (see Figure 5). This means that for any vehicle of a given age, there will be a constant improvement in CWR over a set time period (in this study, 10 years). To use the example provided by the fitted regression line of Figure 5, the predicted CWR for a vehicle manufactured in year $x$ relative to a vehicle manufactured 10 years earlier is (having cancelled out the constants in numerator and denominator):

$$\frac{e^{-0.0418x}}{e^{-0.0418(x-10)}} = e^{-0.418} = 66\%$$

Note that this is constant, not dependent on year of manufacture $x$.


## 4.3    Projected casualties if no action taken ("business as usual")

The evolution of the distribution of the crashed vehicle fleet from year to year consists of the combined impact of new and imported vehicles entering the vehicle fleet and the scrapping of (mainly older) vehicles. If no vehicles were to enter the vehicle fleet and none to exit it (by

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[2] However, Lie and Tingvall (2002) found no relationship between minor injury risk and crashworthiness as measured by NCAP stars.

being scrapped), then the distribution of vehicles by vehicle age (such as shown by the solid line of Figure 10) would shift horizontally along the vehicle age axis. For the distribution to remain the same with respect to vehicle age as time passes, there need to be some vehicles entering and exiting the fleet. Figure 10 shows the distribution of crashed vehicles by vehicle age for the years 2001-2002 combined (solid line). Distributions of inputs (imported new or used cars, represented by the dashed line) to the fleet and subtractions from the fleet (via vehicles being scrapped, represented by the dotted line) for there to be no change two years hence (2003-2004) are also shown. In other words, the distribution of the crash fleet shown in Figure 10 (for 2001/2002) will remain unchanged two years hence if the distributions of vehicles added and scrapped to/from this fleet are as shown. The vehicle ages shown for the vehicles added and scrapped are ages as at 2003/2004 (two years after 2001/2002), so some new vehicles added to the fleet will appear as aged 0 or 1 year old, depending on when in the two year period they appear in the crash fleet.
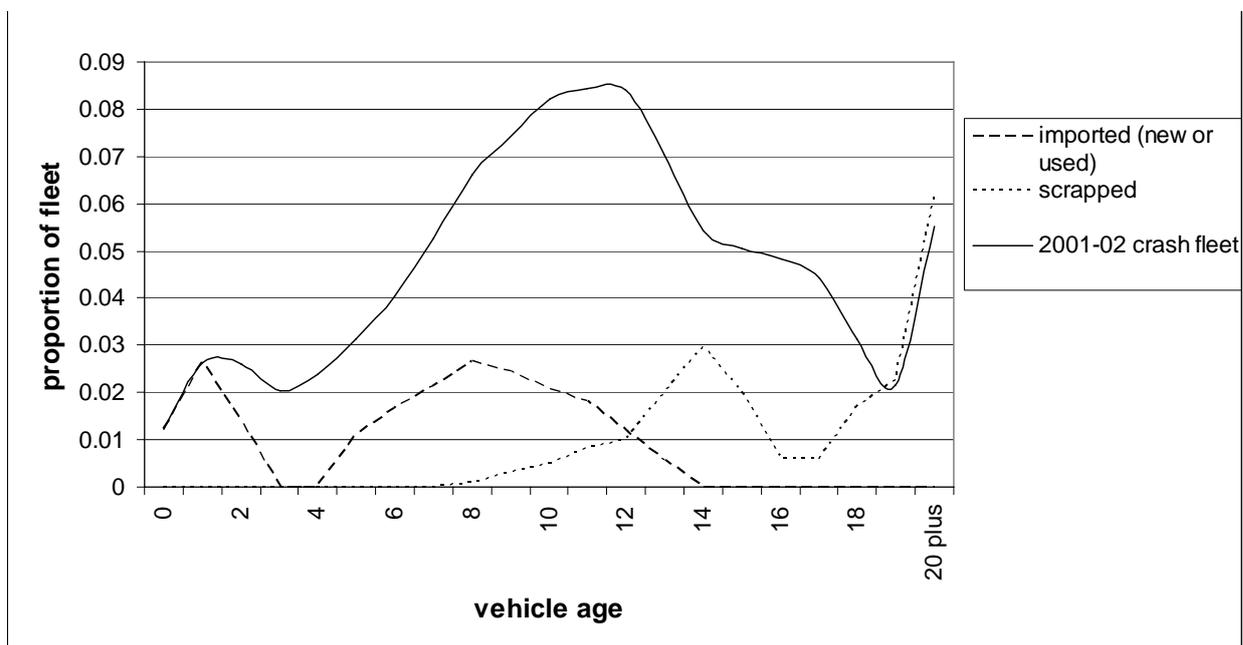


**Figure 10: Example of proportions of crash fleet imported and scrapped over a 2-year period to result in no change to the distribution (2001/2002) of the crash fleet by age.**

Rather than modelling two separate distributions, one for additions to the population of crashed vehicles, one for subtractions, as shown in Figure 10, the approach used in this study, to model various scenarios of changes to the fleet, considered a single distribution, showing net vehicles added to or subtracted from the crash fleet. Figure 11 shows the *net* proportion of vehicles in each age group that needs to enter the fleet (positive proportions) or leave the fleet (negative proportions) for the 2001/2002 crash fleet distribution to remain identical two years hence (shown as a solid line). These are the same figures represented by the dotted and dashed lines in the previous graph, with the scrapped proportions subtracted from the imported proportions. Also shown (by the dotted line) is the change in the distribution required for the fleet to evolve as it actually did, to arrive at the distribution of 2003/2004. These curves are almost identical for the younger vehicles (and Figure 6 confirms that the distributions for 2001/2002 and 2003/2004 are very similar for vehicles aged less than 10 years). The fact that there is a smaller proportion of vehicles aged 10-12 years in 2003/2004 and a larger proportion aged 13-15 years is reflected in both Figures 11 and 6.
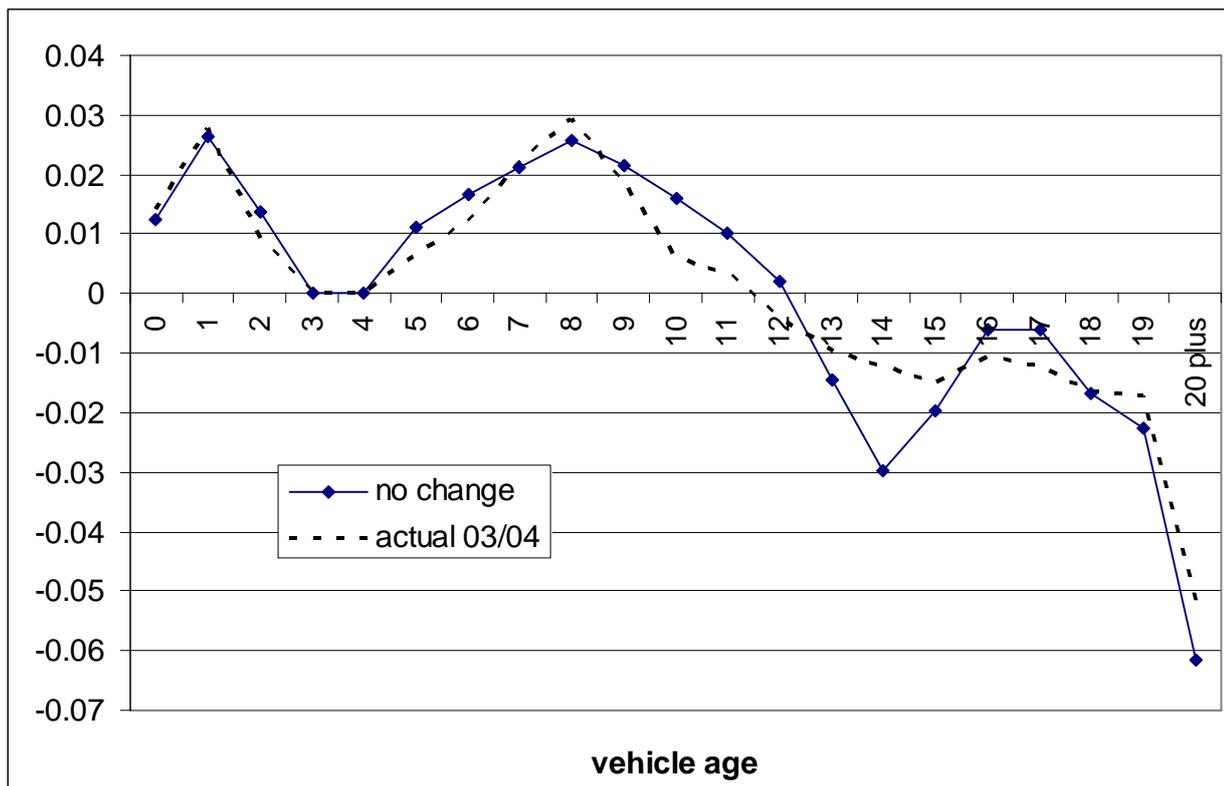
**Figure 11: Net proportion added to (subtracted from) crash fleet in a two-year period from 2001/2002 to result in either no change to the distribution of the crash fleet (solid line) or the actual distribution for 2003/04 (dotted line).**

Each point can be interpreted as the net increase (for positive figures) or decrease (for negative figures) in the crash distribution from the hypothetical situation where all drivers retain their existing vehicle (so no new or imported second-hand vehicles are purchased, no vehicles are scrapped, and all vehicles therefore become 2 years older) to the actual distribution predicted for two years hence, in which some vehicles are introduced to the fleet and others are scrapped. The solid line of Figure 11 can be interpreted as follows: there is a net gain of cars and vans that are new or 1 or 2 years old; if there are any cars imported or scrapped between the ages of 3 and 4, the numbers entering and leaving the fleet cancel one another out; the net gain of vehicles aged 5 to 11 years peaks at age 8 and then diminishes with a net loss to the fleet for cars aged 13 plus. The sort of curves shown by Figure 11, which represents change in the crash fleet, is used to represent the effects of some proposed interventions on the shape of the crash fleet distribution, and can then be used to quantify any benefits accompanying the intervention when combined with estimates of crashworthiness of vehicles by vehicle age. The use of two years' crash data is arbitrary and based on the amount of data required to generate reasonably smooth distributions.

It should also be noted that Newstead and Watson (2005) found that the crashworthiness of vehicles sold new in NZ was not different from the crashworthiness of used imported vehicles with the same year of manufacture. This means that the projections used in this report, which are dependent on estimated and projected crashworthiness by year of manufacture, need not discriminate between NZ new vehicles and used imported vehicles.

## 4.4 Projected casualties given various policy scenarios

### 4.4.1 Background to scenarios

Firstly, the results of a "business as usual" scenario on crash rates are projected. This scenario assumes that the trends in the composition of the NZ light vehicle fleet that have occurred in the past will continue into the future, and that consumer behaviour and the sorts of past policies and regulation affecting the constitution and crashworthiness of the fleet also continue.

The rationale behind the first potential intervention (that restrictions are placed on used cars being imported into New Zealand so that only cars manufactured 7 years ago, or more recently, could be imported) is that many older cars are imported and this may be increasing the average age of the fleet and reducing the impact of improvements to passive vehicle safety that are introduced for new vehicles in the countries of origin (mainly Japan). Two scenarios of regulations taking full effect from the end of 2006 are tested in the following analyses, an optimistic outcome, and a pessimistic scenario of a worst outcome of this policy. The second potential intervention involves regulation of the government fleet.

### 4.4.2 Scenarios under policy changes

1) Scenario 1. This is an optimistic result of import restrictions where only cars manufactured 7 years ago, or more recently, can be imported. People who would have bought an older import decide instead to purchase a newer car (and presumably a more expensive car than the one they might have bought in the absence of the restriction). There is no change in the scrapping of older vehicles (aged 14 years plus) already in the fleet. The line in Figure 12, with the solid squares, represents these changes in the fleet.
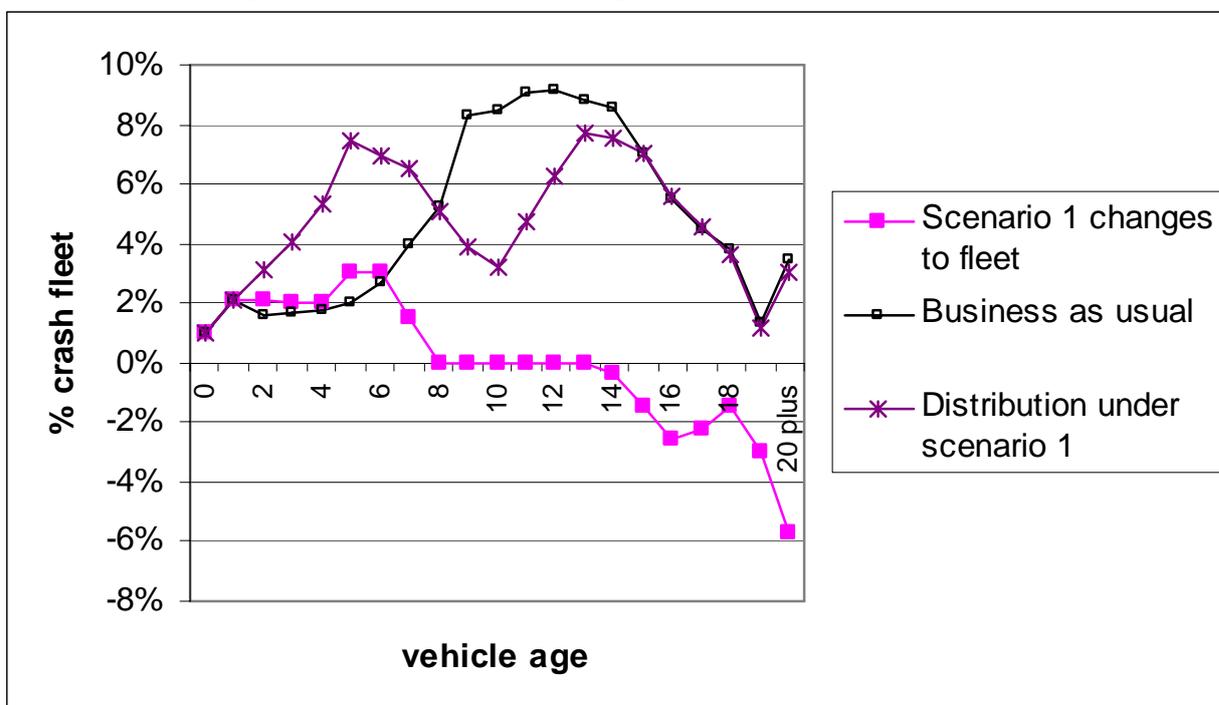


**Figure 12: Scenario 1. Optimistic outcome where buyers choose younger imports, no change in scrapping. Introduced 2006 and compounded over four years**

2) Scenario 2. This is a pessimistic result. There is increased demand for vehicles close to the age threshold (6 and 7 years old) but many drivers are put off by the higher prices for these imports and choose to retain their older vehicles (repairing them rather than scrapping them). The three curves of Figure 13 show the distribution of vehicles new to the fleet minus scrapped vehicles (large squares), the projected distribution of the crash fleet 2009/2010 under 'business as usual' and the distribution in 2009/2010 projected under scenario 2.
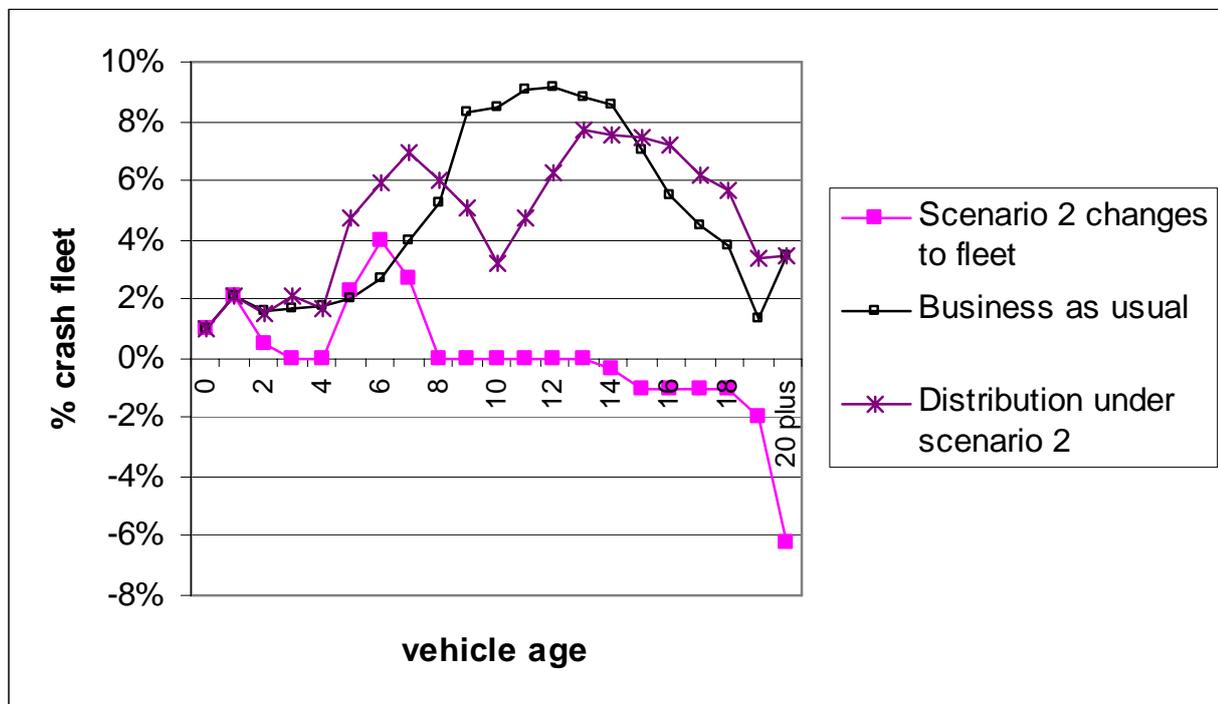


**Figure 13: Scenario 2.** Pessimistic **outcome where buyers are put off by higher prices of imports and retain existing older vehicle introduced 2006 and compounded over four years**

3) Scenario 3. From 2006, all new government fleet vehicles must have the best CWR and aggressivity within the given market group. About 0.4% of the light four-wheeled vehicle fleet are government vehicles[3]. We can assume that about 25% of these are sold per year and replaced with new vehicles. From Newstead et al. (2003), the best (15th percentile CWR) performing recent model vehicles within market group have approximately 85% of the CWR of the group average, and similarly for aggressivity. CWR is projected to improve at the rate predicted by the fitted line of Figure 5. The safety effects of the superior safety vehicles sold as second-hand vehicles in the crash fleet were included in the projection. Although the estimates are therefore somewhat optimistic, it was assumed that superior CWR and aggressivity could be found within the same vehicle. The estimate is also optimistic in that 0.4% of the on-road fleet are government vehicles, but proportionally fewer are likely to be in the crash fleet (see Figure 4, which shows under-representation of new vehicles in the crash fleet relative to the on-road fleet). The improvements in aggressivity were modelled by estimating the effect on the outcome of two-vehicle crashes involving vehicles affected by this policy.

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[3] This was estimated by classifying as government vehicles all those on the motor vehicle register (of licensed vehicles) with government or government agency ownership.

# 5. RESULTS

## 5.1 Projected effects of scenarios

**Table 1: Projected savings in injuries and as a proportion of overall (all road trauma) social cost associated with various scenarios 2010 compared to 2000 or to 'business as usual' (as specified) due to improvements in secondary safety (injury risk given crash occurrence) of fleet**

| Scenario | Description | Light Vehicle injury rate | Overall social cost |
|---|---|---|---|
| **Compared to year 2000** | | | |
| No action 1 | Same trends in purchasing as recent years; crashworthiness with constant proportional improvement | -30% | -22% |
| No action 2 | Same trends in purchasing as recent years; crashworthiness *no change* from 2000-2002 | -28% | -21% |
| No action 3 | 2010 crash fleet *distribution as 2003/4*; crashworthiness with constant proportional improvement | -31% | -23% |
| **Compared to business as usual (no action)** | | | |
| Scenario 1 | No imports >7 years old, optimistic result | -5% | -4% |
| Scenario 2 | No imports >7 years old, pessimistic result | +0.3% | +0.2% |
| Scenario 3 | From 2006, govt fleet new vehicles have best available CWR and aggressivity | -0.1% | -0.1% |

Table 1 shows that the projected safety of the light vehicle crash fleet where there is no regulatory or public information action is quite robust to changes in the assumptions. "No action 1" shows the estimate expected to be the most accurate, where (a) crashworthiness is predicted to continue to improve with a year-to-year change similar to that experienced in the past and (b) the vehicle crash fleet is predicted to continue its year-to-year trends. "No action 2" gives predicted safety given assumption (b), but assuming crashworthiness has plateaued, and remains at the level of the average crashworthiness of 2000-2002 vehicles. "No action 3" assumes improvements in crashworthiness but replaces assumption (b) with the assumption that the crash fleet distribution remains unchanged from 2003/2004. Of course, this last scenario ("No action 3") is unlikely, but the results in Table 1 show that the modelled projections are robust to variations in the shape of the crash fleet distribution by vehicle age. Scenario 2, which presents a pessimistic outcome from age restrictions on imported vehicles, shows a very small *increase* in social cost. Given that this scenario is an unlikely extreme result, it can be concluded that a seven-year age restriction on imported vehicles will almost certainly improve light vehicle[4] injury rates, although such improvement may be modest (at best, a 5% improvement in injury rate and a 4% decrease in social cost, as shown in Table 1).

Note that the predicted social cost changes listed in Table 1 for Scenarios 1 to 3 are in relation to social cost predicted for 2010 under business as usual. Therefore, for the combined effect of "No action 1" and "Scenario 1" it is not valid just to add the -30% estimate for the "No action 1"

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[4] This study restricts its scope to light vehicle safety effects. However, there are likely to be adverse effects on overall safety if some current car drivers lose access to cheap cars and elect to buy and ride motorbikes instead.

scenario estimates to the -4% for Scenario 1 to get -34%. The combined effect for this example is estimated by (1-0.3)x(1-0.04)-1=-32.8%. So the effectiveness projected for Scenario 1 is in terms of 2010 social cost, which is predicted to be only 70% of 2000 social cost. The same considerations apply to Scenarios 2 and 3.

The final scenario considered, in which all new government fleet vehicles must have the best CWR and aggressivity within the given market group, is limited in its effect because of the relatively small NZ government vehicle fleet, even though these fleet vehicles then enter the general vehicle fleet through being sold second hand. Such a policy does present a consistency in governmental attitude favouring crashworthy and non-aggressive vehicles, which in itself may be sufficient justification for the application of this policy despite its modest safety effects.

# 6. DISCUSSION

When considering the estimates shown in Table 1, it is important to remember that the savings in casualties and social cost are those associated only with secondary safety improvements to the fleet (due to improvements in crashworthiness and changes in the age distribution of the fleet). Other improvements in casualty rates are likely to occur due to improvements in primary safety, or avoidance of collisions in the first place, which are likely to accompany improvements in the road network, road use behaviour (speed, alcohol use, etc) and possibly improvements in vehicle technology (improved stability, braking, 'intelligent' systems for crash avoidance, etc). The last factor has often proved disappointing in the past, probably due to drivers' absorption of the safety benefits by driving faster under the conditions favoured by the improved technology. Consideration of primary safety effects is outside the scope of this report. Nevertheless, there will be some apparent improvement in primary safety associated with secondary safety improvements. Some crashes that would have caused injury in the past will not cause injury in the future due to improving crashworthiness. As non-injury crashes are not officially recorded in NZ, this will result in an apparent improvement in primary safety. Consequently, the estimates of this study should be regarded as being slight underestimates as these effects are difficult to quantify. However, as the sorts of crashes affected by this mechanism will be of minor severity, it is not thought that this bias will be large in terms of social cost.

Also excluded from the projections are secondary exposure effects of policy changes. If light vehicles become more expensive to buy as a result of policy restricting the age of imported used vehicles, for example, then some current car drivers and passengers may transfer their travel to other modes, such as motorbikes (an adverse effect on safety, discussed below) or elect to travel less (an adverse effect on mobility, but with safety benefits through reduced exposure to risk). These effects are difficult to predict and are outside the scope of this study.

Figure 5 shows a comparison of the Australian and New Zealand crashworthiness ratings by the year of manufacture. An exponential line fitted to the Australian data shows a faster decreasing annual rate for New Zealand, indicating that New Zealand may not just be experiencing a delayed impact of the sort of improvements in crashworthiness that have already been experienced in Australia. There are some possible explanations. One is that the Australian and NZ fleets present different crash environments, which affects the trends in crashworthiness differently over time. Further research could examine such a possibility by comparing the relative crashworthiness of vehicles in both countries, restricted to collisions with a particular market group (i.e., standardising on collision partner). Another possible explanation for the differential rate of change in CWR over time between the two countries is that the changes occurring in the crashworthiness of the NZ fleet have been experienced more abruptly via the introduction of new or imported second-hand vehicles with superior crashworthiness.

As mentioned above, a seven-year age restriction on imported vehicles will almost certainly improve light vehicle injury rates slightly. Not considered here was the availability of used vehicles in the age range required. For example, if there were insufficient used vehicles available from Japan to fulfil the increased demand following the imposition of age restrictions on imports, then car owners may choose to retain their existing older vehicle, leading to increased ageing of the fleet. Although it is tempting to consider an even more restrictive regime, it is likely that some of the gains resulting from the used import availability in New Zealand could thereby be lost. Such gains may have included increased mobility through the availability of

more affordable vehicles, a reduction in motorcycle[5] use and possibly improvements in the age profile of the fleet (see Section 1.3). For example, throughout the 1980s, there were at least 100 motorcyclist deaths annually. By 2003, there were only 28 (LTSA, 2004). The extent to which such changes can be attributed to used vehicle importation is potentially the topic of further research.

# 7. CONCLUSIONS

In Australia technical improvements flow into the fleet more rapidly than in New Zealand as used imports do not enter the fleet in significant numbers. Since vehicles are new when they enter the fleet and since they are required to meet the Australian Design Rules (ADRs) they incorporate recent advancements in technology. As a result, when the target-setting exercise was first carried out, improvements in crashworthiness had already occurred in Australia at a time where New Zealand was still lagging behind. Using the more accurate crashworthiness results for the New Zealand fleet, the 2010 target of a reduction of 15.5% in total social cost appears likely to be exceeded by a large margin. If trends in fleet constitution and crashworthiness continue, there is predicted to be an improvement (compared to the year 2000) of about 30% in light vehicle casualties and 22% in total social cost.

Compared to this large social cost reduction, the two potential interventions evaluated are predicted to yield fairly modest savings. If age restrictions were imposed on imported vehicles, allowing only those manufactured seven years or less prior to their sale in NZ, it was predicted that, at best, there may be as much as a 4% saving in overall social cost in the year 2010 compared to the "business as usual" approach. Not considered in this report was the potential for motorcycle ownership to increase in response to restrictions on the availability of used vehicles in the lower price ranges. Such an eventuality could have a serious impact on road trauma. Also not considered was the availability of used vehicles in the age range of seven years or fewer since manufacture. If imported used vehicles are not sufficient to fulfil demand, there may be an adverse impact on fleet crashworthiness as drivers retain older vehicles that would otherwise have been scrapped.

The final scenario considered, in which all new government fleet vehicles have the best crashworthiness and aggressivity within the given market group, was limited in its effect because of the relatively small NZ government vehicle fleet. Only a 0.1% saving in social cost was predicted as the most optimistic result of this scenario.

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[5] Per distance travelled, a motorcycle ridden under New Zealand road conditions is estimated to be about 18 times as risky as a car (LTSA, 2000).

# 8. ASSUMPTIONS AND QUALIFICATIONS

The results and conclusions presented in this report are based on a number of assumptions and warrant a number of qualifications that the reader should note. These are listed in the following sections.

## 8.1 Assumptions

It has been assumed that:

- Police crash reports accurately recorded driver injury, hospitalisation and death. More particularly, it is assumed that there is no tendency to record crashes differently for vehicles of different ages. Police recorded vehicle years of manufacture will be subject to some degree of error; however it is assumed that such errors are not changing systematically with time.

- The estimated crashworthiness of the vehicle (probability of fatal or serious injury to the driver given crash occurrence) is also a good estimate of the vehicle's ability to prevent minor injuries to the driver and passengers. As minor injuries in light vehicle crashes are a relatively small proportion (about 12%) of total social cost, the violation of this assumption would incur relatively little bias in the estimates.

- The crashworthiness of the vehicle in terms of the injury outcome of the driver is reflective of that vehicle's ability to protect other vehicle occupants. Again, injuries in light vehicles are mainly driver injuries, constituting the majority of the social cost.

- There will be no drastic change in the transportation environment during the next five years. Such changes may alter the accuracy of the predicted injury rates.

- The form of the models and their extrapolation are approximately correct and valid at least to the year 2010.

## 8.2 Qualifications

The results and conclusions warrant at least the following qualifications:

- The scope of the analysis in this report only covers secondary safety features of the light four-wheeled vehicle fleet. This is in keeping with the analysis on which the 2010 targets are based. This means that changes in mobility have not been accounted for. The projections have been made purely on predicted changes in the crash fleet age distribution and trends in the crashworthiness of given aged vehicles over time.

- The savings estimated here refer to a reduction in injuries *given crash occurrence*. It is likely that some features that improve crashworthiness will also affect some minor crashes to the extent that some will not even be recorded officially as no injury resulted. Such crash reductions have not been accounted for here, and there will be slight underestimation of the benefits as a result.

- Changes in the constitution of the vehicle fleet will not have a large effect on the projected crashworthiness ratings and they are likely to be gradual (see Newstead et al., 2004).

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