TRENDS IN CRASHWORTHINESS OF THE NEW ZEALAND VEHICLE FLEET

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ABSTRACT

Crashworthiness ratings measure the relative safety of vehicles in preventing death or serious injury to their drivers in crashes. This study has successfully estimated trends in the crashworthiness of the light passenger vehicle fleet in New Zealand by both year of manufacture and year of first registration in New Zealand. Years of vehicle manufacture from 1964 to 2002 have been considered through analysis of data on police reported crashes involving injury in New Zealand over the period 1991 to 2002. Estimates have been obtained for the fleet as a whole as well as broken down by vehicles sold new in New Zealand and vehicles imported second-hand.

There was statistically significant improvement of 50% in the crashworthiness of New Zealand light passenger vehicles over the study period. The majority of the measured improvement occurred from 1983 to 2002, a period in which New Zealand vehicle safety was affected by several competing factors including engineering improvement, increasing used vehicle imports and increased Government regulation. Level of absolute crashworthiness and trends on a year of manufacture basis were similar for used imports to those for vehicles sold new in New Zealand. Estimated crashworthiness trends of used import vehicles by year of first registration in New Zealand showed statistically significant improvements from 1978 to 1998. Absolute levels of crashworthiness and improvements by year of first registration paralleled those seen in the analysis by year of manufacture but occurred some 6 years later, a lag equivalent to the average age of the used imported vehicles over the study period. Implications of the used import program on overall vehicle safety in New Zealand are discussed.

BACKGROUND AND AIMS

Background

Crashworthiness ratings assess the relative performance of different vehicle models in preventing injury to their occupants in the event of a crash. A system of rating vehicle crashworthiness by examining injury outcomes to drivers in real crashes has been developed by the Monash University Accident Research Centre (MUARC, Newstead et al, 2004). The rating is a measure of the risk of death or serious injury to a driver of that vehicle when it is involved in a crash. This risk is estimated from large numbers of records of injury to drivers involved in crashes reported to police.

A principal focus of the MUARC crashworthiness ratings study has been to track historical improvements in the average crashworthiness of the Australian vehicle fleet by year of manufacture since 1964. The study has showed that the crashworthiness of passenger vehicles in Australia has improved over the years of manufacture 1964 to 2002 (Newstead et al, 2004). Particularly rapid improvement was observed over the years from about 1970 to 1979 in response to the implementation of a number of Australian Design Rules (ADRs) for motor vehicle safety which previous research had shown to be effective in providing occupant protection.

The New Zealand and Australian vehicle fleets differ significantly in their mix of vehicle makes and models as well as the standards they were manufactured to meet. This is partly a result of the program of importing used vehicles into New Zealand (mainly from Japan) which began to have effect in 1987 when the percentage of used imports in new registrations in New Zealand rose from about 5% to about 13%. The levels of used imports rose again to about 50% over the next three years and at present about two-thirds of the newly registered light vehicles are used imports.

The regulatory framework governing vehicle safety in New Zealand is also quite different to that in place in Australia. Australia has a very active vehicle manufacturing industry and requires that all vehicles must be manufactured in compliance with the Australian Design Rules (ADRs), so the quality is controlled at manufacture. By contrast New Zealand now imports all its light vehicles and their quality is controlled at import. The various Land Transport Rules require that vehicles must have been manufactured in accordance with approved standards but they also provide a choice of equivalent standards, not just the ADRs, because the vehicles are sourced from other markets. Although both countries mandate the same standards the timing of their implementation is quite different which would be expected to lead to differences in crashworthiness by year of vehicle manufacture.

Trends in crashworthiness by year of vehicle manufacture reflect the composition of a particular vehicle fleet in terms of the makes and models of vehicles in the fleet as well as the regulatory framework for vehicle safety in the country being examined. Reflecting the noted differences in these factors between the two fleets, it is likely that trends in crashworthiness by year of vehicle manufacture in New Zealand are different to those measured in Australia.

Project Aims

The aim of this project was to investigate the relationship between vehicle crashworthiness and vehicle year of manufacture for the New Zealand passenger vehicle fleet as a whole. Analysis aimed to estimate trends in crashworthiness separately for vehicles sold new in New Zealand and for imported used vehicles. To assess the safety of the used imports brought into New Zealand in any particular year, the project also aimed to assess the trend in safety of the New Zealand used imports by examining crashworthiness by year of first registration in New Zealand.

DATA

NZ has an established database of police-reported crashes over many years stored in the Crash Analysis System (CAS) database managed by Land Transport New Zealand and covers both injury and non-injury crashes. Whilst non-injury crashes are available from CAS, the reporting coverage of non-injury crashes in NZ is not clear due to it not being mandatory for a non-injury crash to be reported to the Police. Hence only injury crash data from New Zealand were reliably available for estimating vehicle safety ratings.

Data on all injury crashes occurring in New Zealand over the years 1991 to 2002 were supplied for analysis. It covered information on 123,707 crashes involving 211,408 traffic units after exclusion of motorcycles, bicycles, pedestrians and heavy vehicles. Fields included in the data relevant to the analysis were: year of crash, speed limit at crash location, number of vehicles involved, level of urbanisation of crash location, driver age, driver gender and Injury level of driver (killed, hospitalised, other injury, not injured).

Detailed information on vehicle make, model and body type, year of manufacture, year of first registration in New Zealand and import status (imported new or second hand) for vehicles appearing in the crash data were obtained through interrogation of the New Zealand vehicle register. Registration details matching the crashed vehicle were obtained through matching of registration plate number and comparing date of first registration in New Zealand and the date of crash to ensure accurate matching. Registration details were obtained for 186,872 of the 211,408 units appearing in the crash data. Only vehicles manufactured after 1964 and only entries coded as cars, station wagons, vans or utilities were relevant to the analysis. This left 143,723 light passenger vehicles for analysis from which the drivers' injury outcomes were used for estimation of the crashworthiness measure.

METHODS

The crashworthiness rating (C) is a measure of the risk of death or serious injury to a driver of a car when it is involved in a crash. It is defined to be the product of two probabilities (Cameron et al, 1992): i) the probability that a driver involved in a crash is injured (injury risk), denoted by R; and ii) the probability that an injured driver is hospitalised or killed (injury severity), denoted by S. That is C = RxS. Folksam Insurance, who publishes the well-known Swedish ratings, first measured crashworthiness in this way (Gustafsson et al, 1989). This method has previously been used to produce crashworthiness ratings by vehicle make and model for the Australian and New Zealand vehicle fleet (Newstead et al, 2004).

Because non-injury crashes are not reliably reported in the New Zealand crash data, injury risk cannot be measured directly from the data (as a simple ratio of injured drivers over total involved drivers) as it is in calculating the vehicle specific ratings of Newstead et al (2004). The alternative of calculating the proportion of injured drivers amongst those involved in injury crashes results in a biased estimate of injury risk. To overcome these problems, an alternative measure of injury risk proposed in Cameron et al (2001) and further demonstrated in Newstead et al (2005) has been used here. It is based on the paired comparison approach comparing driver injury outcome in two car crashes and leads to unbiased injury risk estimates. The injury risk measure is the conditional probability of driver injury risk in the vehicle being rated given the driver of the colliding vehicle is injured.

The new injury risk measure used here has been combined with an injury severity measure identical to that used in Newstead et al (2004) to produces a crashworthiness measure identical in construction and concept to the MUARC measure of Newstead et al (2004) but based on injury crashes only. The only key difference between the MUARC measure of injury risk and the new measure used here is the scaling of the estimates. The new measure of injury risk is conditional on the driver of the other vehicle in a two-vehicle crash being injured and hence the average injury risk will be higher than when all crashes are considered, as is the case for the MUARC method. Consequently, the absolute estimates of crashworthiness by year of manufacture estimated in this study for New Zealand are not comparable with those estimated for Australia by Newstead et al (2004). However, the relative trends in crashworthiness by year of vehicle manufacture estimated for each country are consistent and comparable.

Both the injury risk and severity measures by year of vehicle manufacture have been estimated using logistic regression analysis. The purpose of using logistic regression models was to compensate for the effects of possible factors, other than those related to the vehicle, that might have influenced the crash outcomes in terms of driver injury risk or severity. These included driver sex (male, female), driver age (≤25 years; 26-59 years; ≥60 years), speed limit at the crash location (<80 km/h; ≥80 km/h) and year of crash (1987, 1988, … ,2002). For crashworthiness injury severity the number of vehicles involved in the crash (one vehicle; >1 vehicle) was also considered. These variables were chosen for consideration because they were available in the New Zealand database and have been shown to have a significant relationship to injury outcome in the Australian vehicle safety ratings. Logistic models were obtained separately for crashworthiness injury risk and crashworthiness injury severity because it was likely that the various factors would have different levels of influence on these two probabilities. All data was analysed using the Logistic Regression procedure (PROC LOGISTIC) of the SAS statistical package (SAS, 1989). Methods for calculating confidence limits on the ratings are described in Newstead et al (2004).

RESULTS

Crashworthiness by Year of Manufacture

Injury risk by year of manufacture was estimated from the data on 33,849 drivers of 1964-2002 model vehicles in two vehicle collisions during 1991 to 2002 with complete records, 14,799 of whom were injured. For vehicles sold new in New Zealand, analysis was performed on data relating to 19,066 involved drivers, 8,264 of who were injured. For used imported vehicles, analysis was performed on data relating to 8,814 involved drivers, 3,678 of who were injured. Injury severity was estimated from records on 73,809 drivers who were injured in crashes in New Zealand during 1991-2002, 14,828 of whom were severely injured (killed or admitted to hospital). For vehicles sold new in New Zealand, injury severity was estimated from data relating to 42,090 injured drivers, 8,368 of who were severely injured. For used import vehicles, the severity analysis was performed on data relating to 9,269 injured drivers, 3,918 of who were severely injured. The crashworthiness estimates for each year of manufacture were obtained by multiplying the corresponding individual injury risk and injury severity estimates.

The crashworthiness estimates and their 95% confidence limits are plotted for each year of manufacture for all vehicles (both new and used imports) and for new and used imported vehicles separately in Figures 1, 2 and 3 respectively. Confidence limit width generally reflects the amount of data available for analysis in each year of manufacture.

Figure 1: *Crashworthiness by year of manufacture (with 95% confidence limits) for all vehicles (both new vehicles and used imports).*

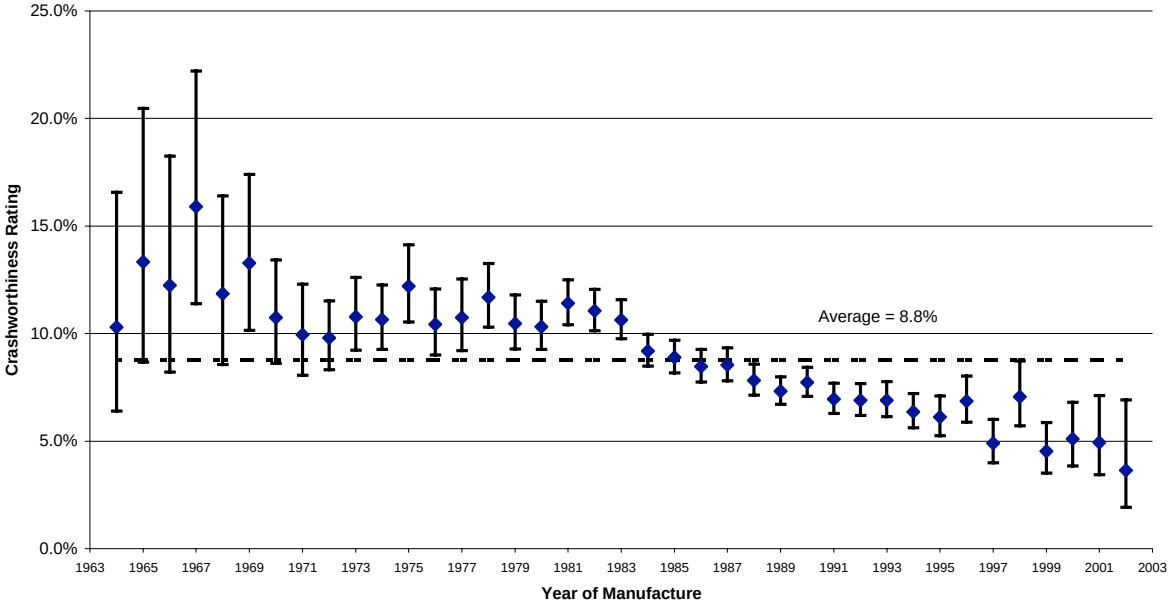


Figure 2: *Crashworthiness by year of manufacture (with 95% confidence limits): Vehicles sold new in New Zealand*

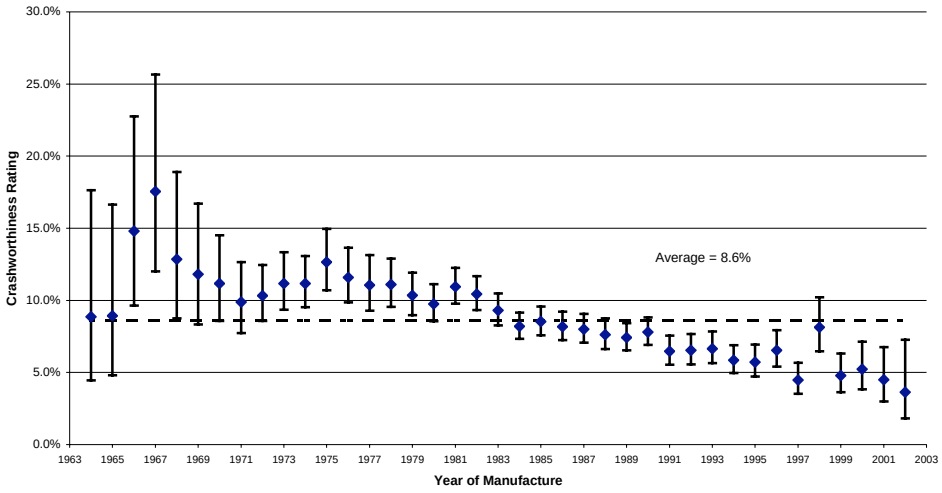
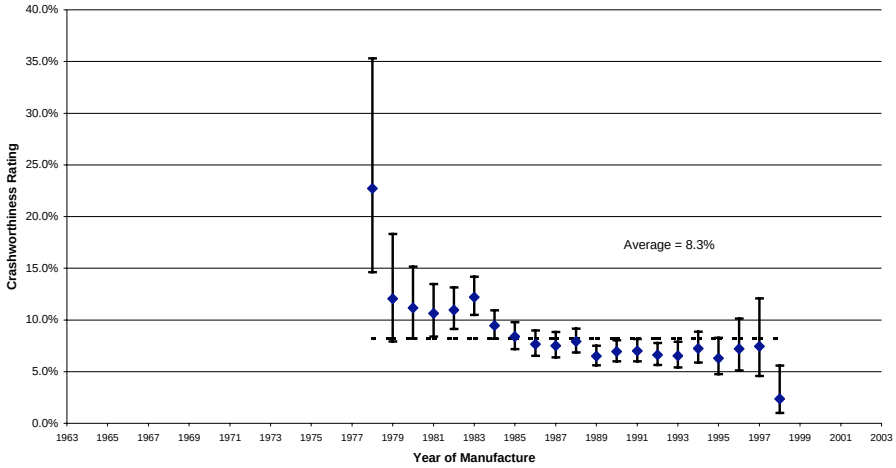


Figure 3: *Crashworthiness by year of manufacture (with 95% confidence limits): Used Imports*

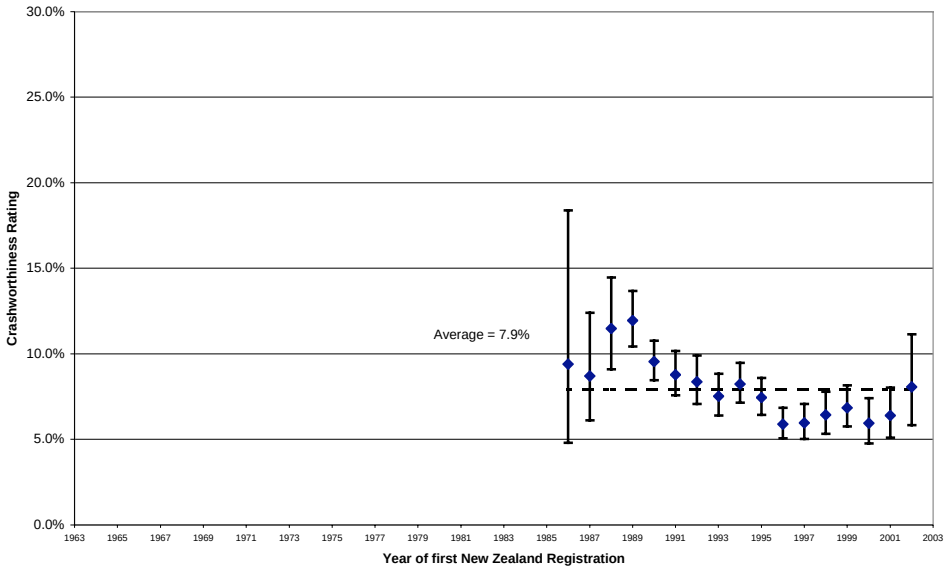


Crashworthiness by Year of First Registration in New Zealand

As well as estimating crashworthiness trends by year of manufacture, crashworthiness of the used-import subset of the vehicle fleet by year of first registration in New Zealand has also been estimated. The purpose of this analysis was to monitor trends in the average crashworthiness of used imports coming into New Zealand by year of import. This is in contrast to the year of manufacture analysis which examines trends in crashworthiness-related safety engineering improvements in vehicles over time. Analysis of crashworthiness by year of first registration in New Zealand was carried out in the same way as for the year of manufacture analysis. The only fundamental difference was that the variable indicating year of manufacture in the analysis was replaced by the variable indicating year of first registration. Analysis by year of first registration in New Zealand has focused primarily on used import vehicles as the year of manufacture and first registration in New Zealand will generally be the same for vehicles sold new in New Zealand.

Injury risk by year of first registration in New Zealand for used imported vehicles was estimated from data on 8,728 involved drivers, 3,631 of whom were injured. Injury severity by year of first registration in New Zealand was estimated from the data on 18,460 injured drivers, 3,515 of whom were severely injured. Estimates of crashworthiness by year of vehicle first registration in New Zealand were obtained by multiplying the corresponding estimates of injury risk and injury severity. The resulting crashworthiness estimates and their 95% confidence limits are presented in Figure 4

Figure 4: *Crashworthiness by year of first registration in New Zealand (with 95% confidence limits): Used Imports*



DISCUSSION

Analysis presented in this paper has been able to quantify the long-term trends in the crashworthiness of light passenger vehicles in New Zealand both by year of vehicle manufacture and year of first registration in New Zealand. Before interpreting the results of the analysis, it is useful to give a brief summary of the history of the vehicle industry and its regulation in New Zealand.

For most of the twentieth century, New Zealand had a local vehicle industry. In the late 1980s, progressive removal of import controls and reduction of tariffs was initiated. Furthermore, a Government decision was made to allow used vehicles to be imported into New Zealand to provide a wider source of relatively new and affordable vehicles and to attempt to reduce the number of motorcycles in the New Zealand fleet. 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. The percentage of used imports in annual vehicle registrations grew progressively from less than 10% prior to 1986 to around 68% by 2002. 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. The vast majority of the used light passenger vehicles imported into New Zealand come from Japan.

Like most countries, New Zealand has a system of regulations to govern the safety of vehicles on the road. 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 the 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. Since 1990, the vehicle standards policy in New Zealand has been clarified by Government 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.

Trends by Year of Manufacture

Trends in estimated crashworthiness by year of vehicle manufacture for the New Zealand light passenger vehicle fleet as a whole show statistically significant improvement in crashworthiness in vehicles manufactured over the period 1964 to 2002. Estimates in Figure 1 show that the crashworthiness of vehicles manufactured in the 1960s was relatively poor, although the confidence limits on these estimates are relatively wide due to the small numbers of these vehicles in the available data. For vehicles manufactured during the 1970s, the crashworthiness estimates are relatively static showing no trend to improving or worsening crashworthiness. From about 1984 onwards, however, there is a consistent trend to improving crashworthiness. Estimates suggest that the risk of driver death or serious injury in a crash in a vehicle manufactured in the early 21st century is about half that of the driver of an early 1980s vehicle.

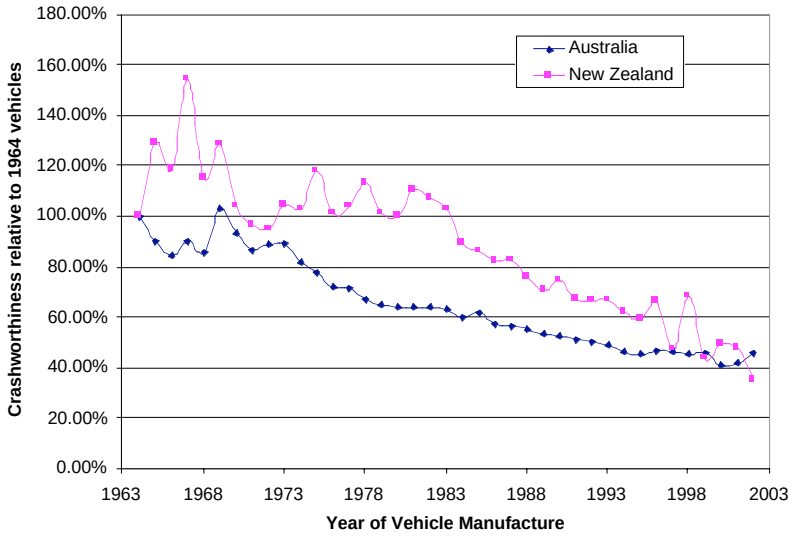
Trends in crashworthiness for vehicles sold new in New Zealand and imported used, shown in Figures 2 and 3 respectively, are similar for the two vehicle groups. They both show evidence of a trend towards improving crashworthiness with later year of manufacture over the years 1978 to 1998 for which estimates are available for both vehicle groups. In both instances, average crashworthiness improved from around 11-12% in the late 1970s to around 6-7% in the late 1990s, a relative improvement of around 40% over the period. The similarity of the results for the different vehicle groups suggests that both increased safety regulation and general safety engineering improvements in vehicles appear to have had the same benefits for used imports as for vehicles sold new in New Zealand, when assessed on a year of manufacture basis. It also confirms that, on a year of manufacture basis, the level of secondary safety in used imported vehicles appears to be equivalent to that found in vehicles sold new in New Zealand.

Because of the relatively similarity in types of vehicles in the Australian and New Zealand vehicle fleets, it is interesting to compare the relative trends in safety improvement between the vehicle fleets of the two countries. This comparison is also of interest to determine if the quite different strategies for vehicle safety regulation adopted in the two countries have led to fundamental difference in the patterns of vehicle safety improvement from year to year. One difficulty in making this comparison occurs because the measure of crashworthiness by year of manufacture used in each jurisdiction was scaled differently, reflecting the differences in the available data. Estimates from each country could not be scaled to a common basis for comparison because the average absolute injury risk cannot be calculated from the injury-only crash data available from New Zealand. However, comparisons in relative changes in crashworthiness by year of manufacture can be made between the two countries.

The relative change in crashworthiness by year of vehicle manufacture using 1964 as the base year is shown in Figure 5 for both Australia and New Zealand. Crashworthiness by year of vehicle manufacture in Australia showed an improvement of around 30% between the end of the 1960s and the end of the 1970s in response to the introduction of a program of new Australian Design Rules concerning vehicle safety. After a relative plateau in the early 1980s

a further steady improvement of about 25% in vehicle crashworthiness has been estimated between 1985 and 2002. This means that the average risk of death or serious injury to a driver in a crash in an Australian vehicle manufactured in 2002 is on average about half that of a vehicle manufactured in the 1960s. The crashworthiness of New Zealand vehicles manufactured in the 1960s was also poor compared to subsequent years. Unlike Australia, New Zealand had little improvement in crashworthiness of vehicles manufactured during the 1970s and first half of the 1980s. Only since years of manufacture from about 1984 has New Zealand seen consistent and dramatic improvements in average vehicle crashworthiness. For New Zealand vehicles manufactured from the early 1980s to the early 2000s crashworthiness has improved by about 50%, equivalent to the total improvement seen in Australian vehicles over the period from 1964 to 2002.

Figure 5: *Crashworthiness by year of vehicle manufacture as a percentage of 1964 vehicle crashworthiness: Australia and New Zealand.*



The key difference in crashworthiness improvement by year of vehicle manufacture between Australia and New Zealand then appears not to be the magnitude of the improvement but the relative timing of the improvement. The greatest improvements in Australia were observed during the 1970s, the period during which the greatest numbers of new regulations concerning vehicle safety were introduced. Although improvements have also been estimated in Australia after these years of manufacture they have occurred at a slower rate. In contrast the greatest improvement in crashworthiness has been observed in New Zealand for vehicles manufactured from the mid 1980s to 2002. This is also the period in which the greatest movement in introducing vehicle safety regulations in the form of the VSRs and Land Transport Rules took place. Estimated trends from both countries suggest that regulation of vehicle standards is an effective way to achieve the big gains in vehicle safety performance.

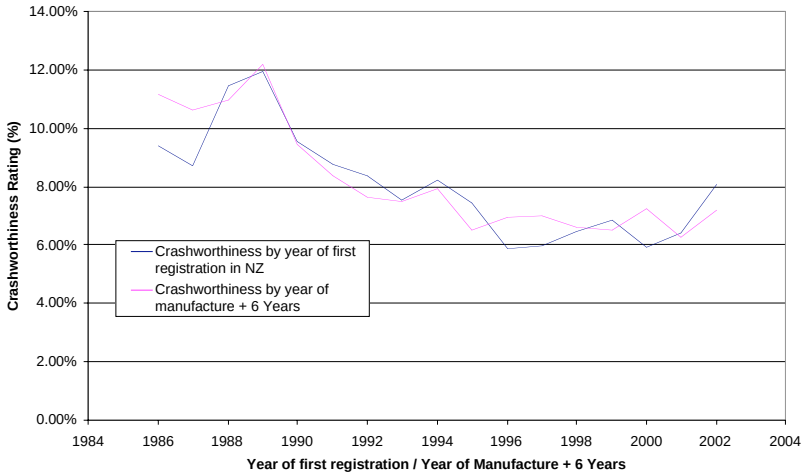
Trends by Year of First Registration in New Zealand

Analysis of trends in vehicle crashworthiness by year of first registration in New Zealand has aimed to assess the average crashworthiness of second hand vehicles being imported into New Zealand in each calendar year. It further aimed to assess the impact of the second hand import program on the overall safety of all vehicles registered in New Zealand each year.

The age profile of used import vehicles in New Zealand was fairly static over the study period. Whilst vehicles up to about 12 years old were imported, with some even older than

that, the majority of used imports ranged from 3 to 9 years old when imported, with the median age being around 6 years. Figure 6 shows the point estimates of crashworthiness by year of first registration in New Zealand superimposed on the estimates of crashworthiness for used imported vehicles by year of manufacture translated 6 years to the right, the average age of the used imports. The two curves are almost identical confirming that the average crashworthiness of used imports brought into New Zealand in any year is the same as the average crashworthiness of vehicles sold new in New Zealand six years earlier. Both curves confirm the trend to improved crashworthiness of used imported vehicles in later years of manufacture with the average serious injury risk to drivers in a crash being reduced by around 40% over the period of the analysis.

Figure 6: *Crashworthiness by year of manufacture translated 6 years forward and Crashworthiness by year of first registration in New Zealand: Used Import Vehicles*



What the analysis shows in practice is that the used imported vehicles being brought into New Zealand are as safe on average as the vehicles sold new in New Zealand when compared on a year of manufacture basis. However, because the used vehicles are on average 6 years old when entering the country, the safety benefits of the latest vehicle technologies seems to take 6 years longer to be seen in the New Zealand fleet than if the vehicles were sold new in New Zealand. Given that the proportion of used import vehicles in the total volume of new vehicle registrations has been growing over the last decade or more, a corresponding increased delay in the introduction of latest vehicle safety technology in the New Zealand fleet will be resulting. In other words, the used import program is resulting in a poorer average crashworthiness of all vehicles registered in New Zealand each year compared to the situation where only new vehicles were sold.

However, before concluding that the used import program is compromising the safety of the New Zealand vehicle fleet, the effect of the used import program on average fleet age must be considered. If the used import program has reduced the average age of the New Zealand vehicle fleet by more than 6 years, there may be some net benefit in the program. A comprehensive investigation of how the used import program has affected the average age of the New Zealand fleet, particularly in the face of increasing motorisation, is beyond the scope of this study but is recommended as further research. It might also be expected that the average age of used imports will decrease from 2002 as a result of changes in the Land

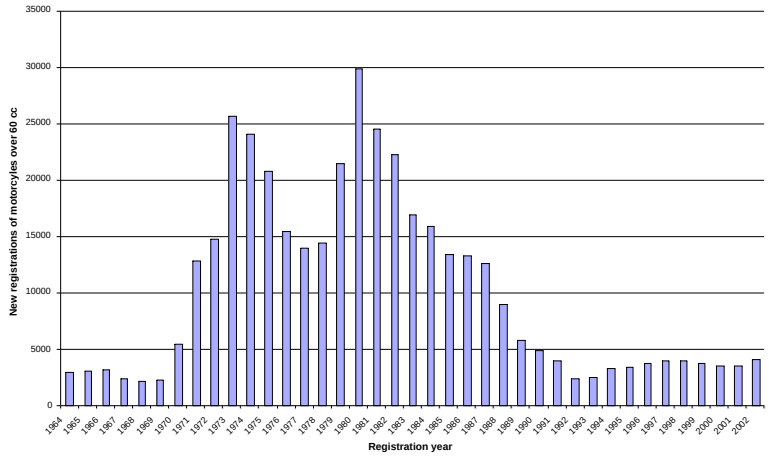
Transport Rule concerning frontal impact compliance. From April 2002, all vehicles newly registered in New Zealand must comply with frontal impact occupant protection standards, as compared to only vehicles manufactured from March 1999 in the previous rule. The modified rule will make it difficult to import used vehicles manufactured before 1996, the date after which Japanese domestic vehicles manufactured had to meet the Japanese frontal impact standard accepted under the New Zealand rule.

Effects on Motorcycle Registrations and Crashes

One of the objectives of the used import vehicle program in New Zealand was to reduce the high motorcycle use the country had seen during the 1970s and 1980s. Consequently, assessing the net impact of the used vehicle import program in New Zealand would not be complete without at least a brief examination of the trends in motorcycle registrations and deaths and injuries resulting from motorcycle crashes in New Zealand.

Figure 7 gives annual motorcycle registrations in New Zealand from 1964 to 2002. After averaging over 15,000 registrations annually during the 1970s and the first half of the 1980s, motorcycle registrations dropped sharply during the late 1980s to a consistent level of less than 5000 per annum from 1991 onwards.

Figure 7: *Motorcycle registrations in New Zealand: 1964-2002*



The drop in annual motorcycle registrations shows a high degree of correlation with the dramatic increase in the proportion of used import registrations in New Zealand from around 1985 onwards. Whilst the evidence of a correlation is not proof that the used import program caused the drop in motorcycle registrations, it is considered likely that this is the case

Corresponding to the drop in motorcycle registrations in New Zealand has been an equally large drop in reported deaths and injuries associated with motorcycles in the official crash statistics. Motorcyclist deaths showed similar trends to injuries and have dropped from around 70 per annum in the early 1990s to around 30 per annum by 2002. The sustained progressive reduction in motorcyclist death and injury during the 1990s was maintained even though new registrations reached a plateau over the period. This is likely due to the total population of motorcycles reducing as older motorcycles were taken off the road but may also in part be due to general road safety improvement in New Zealand over the period.

Encouraging road users off motorcycles and into cars may not necessarily reduce the total number of crashes across the system although it is likely given the inherently more stable nature of a car versus a motorcycle. The real benefit in encouraging the use of cars rather than

motorcycles is, however, in reducing the severity of injury outcome in the event of a crash (i.e. the crashworthiness of the transport mode). It is a well established fact that cars offer much greater occupant protection in a crash than is afforded to motorcycle riders in a crash. It is beyond the scope of this study to establish the actual net benefits of the used import vehicle program in New Zealand through reduction in motorcycle use. However, the benefit is likely to be substantial.

CONCLUSION

This study has been successful, for the first time, in quantifying trends in crashworthiness of the New Zealand light passenger vehicle fleet both by year of manufacture and year of first registration. There was statistically significant improvement in the crashworthiness of New Zealand light passenger vehicles over the study period of 50%. The majority of the measured improvement occurred from 1983 to 2002, a period in which New Zealand vehicle safety was affected by several competing effects including engineering improvement, increasing used vehicle imports and increased Government regulation. Level of absolute crashworthiness and trends on a year of manufacture basis were similar for used imports to those for vehicles sold new in New Zealand. Estimates of crashworthiness trends of used import vehicles by year of first registration in New Zealand showed statistically significant improvements from 1978 to 1998. Absolute levels of crashworthiness and improvements by year of first registration paralleled those seen in the analysis by year of manufacture but occurred some 6 years later, a lag equivalent to the average age of the used imported vehicles over the study period.

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