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ESTIMATION OF THE EFFECT OF IMPROVED AVERAGE SECONDARY SAFETY OF THE PASSENGER VEHICLE FLEET ON ANNUAL COUNTS OF SERIOUS INJURY FOR AUSTRALIA AND NEW ZEALAND: 1991-2006

by

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Abstract:
The aim of the present analysis is to develop an index of the average secondary safety of the passenger vehicle fleet in Australia and New Zealand and then quantify what effect improvements in secondary safety have had on the number of people seriously injured or killed due to road crashes. Police-reported crash data from five Australian states and New Zealand were used to define the secondary safety index. The secondary safety index was based on the point estimates of individual ratings from the 2008 update of the Vehicle Safety Ratings (Newstead, Watson & Cameron, 2008a). A baseline secondary safety index was also defined as being equal to the secondary safety index observed for the fleet in 1991. After estimating the annual number of seriously injured or killed occupants for each year in the period 1991-2006, the baseline secondary safety index was used to estimate how many occupants would have been seriously injured or killed if the secondary safety of vehicles in the fleet had not improved since 1991.

The average crashworthiness of Australian passenger vehicles was estimated to be 4.5% in 1991, improving steadily over the next fifteen years to be 3.3% in 2006. It was also found that the secondary safety index did not vary greatly when disaggregated across the five Australian jurisdictions. If the secondary safety of the Australian fleet had not improved in such a manner, it is estimated that 39,000 additional cases of occupants being seriously injured or killed would have occurred over the period 1991-2006, which is 14.6% higher than the total number of serious injuries and fatalities observed during this period. When considering fatalities alone, the improved secondary safety of the Australian fleet is estimated to have saved 2,700 lives over the period 1991-2006.

The average crashworthiness of the New Zealand fleet was estimated to be about 7.5% in 1991 and 4.2% in 2006. The improved secondary safety of the New Zealand fleet over this period was estimated to have resulted in approximately 12,600 fewer cases of seriously injured or killed road users. When considering fatalities alone, the improved secondary safety of the New Zealand fleet over the period 1991-2006 was estimated to have saved about 1,900 lives.

Key Words: (IRRD except when marked*)
Injury, Collision, Statistics, Crashworthiness, Secondary Safety, Risk

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EXECUTIVE SUMMARY

In recent years much effort has been made to improve the ability of vehicles to protect their occupants when involved in a crash. The ability of a vehicle to protect its occupants is referred to as its *secondary safety*. In 1994, Cameron, Finch & Le developed a statistical procedure to rate the secondary safety of passenger vehicles in the Australian fleet. These ratings measured the risk of a driver being seriously injured given involvement in a police-reported crash. This metric has been given the name *crashworthiness*. The most-recent update of the ratings used data from New South Wales, New Zealand, Queensland, South Australia, Victoria and Western Australia. The primary purpose of these ratings is to enable the consumer to make informed decisions about vehicle safety when deciding which vehicle to buy. However, the ratings have also been used in many other research contexts. The ratings also have the potential to be used by governments and road safety strategists to better understand how improvements to the secondary safety of their fleet can affect the accuracy of attempts to estimate the future burden of road trauma.

Recently, Newstead, Watson & Cameron (2008a) grouped vehicles by their year of manufacture and rated the crashworthiness of each of these groups. This allowed the secondary safety of vehicles manufactured in different years to be compared and demonstrated how, in general, newer vehicles offered better protection than older vehicles. Although such analyses quantify the improved safety of new vehicles, they are not useful in determining how vehicle safety advances have improved the absolute safety of entire fleets. This is because they do not take into account how long older vehicles remain in the fleet.

The aim of the present analysis is to develop an index of the average secondary safety of the passenger vehicle fleet in Australia and New Zealand and then quantify what effect improvements in secondary safety have had on the number of people seriously injured or killed due to road crashes. The report is limited to examining the effect of improved secondary safety since 1991, as this was the earliest year for which the required crash data could be obtained. The methodology employed in the present report is similar to that used by Keall & Newstead (2008) who developed an index that rated the average secondary safety performance for the New Zealand vehicle fleet over time.

The crash data used to define an index of secondary safety were the same as that used in the 2008 update of the Vehicle Safety Ratings by Newstead, Watson & Cameron (2008a). Therefore data from five Australian states and New Zealand were used to define the secondary safety index. The methodology section of the report explains how data for vehicles manufactured from 1964 onwards were used to define the secondary safety index but data for vehicles manufactured prior to 1982 were analysed separately (and in a different way) to data for more-recently manufactured vehicles.

The secondary safety index was based on the point estimates of individual ratings from the 2008 update of the Vehicle Safety Ratings (Newstead, Watson & Cameron, 2008a). Each vehicle in the dataset was assigned a crashworthiness rating and the average rating within each crash year in the period 1991-2006 was then estimated. For each record, the crashworthiness rating was assigned in one of three ways, depending on whether a model-specific rating was available. If a model-specific rating was not available for a particular record; market group and year of manufacture variables were used to assign a rating.

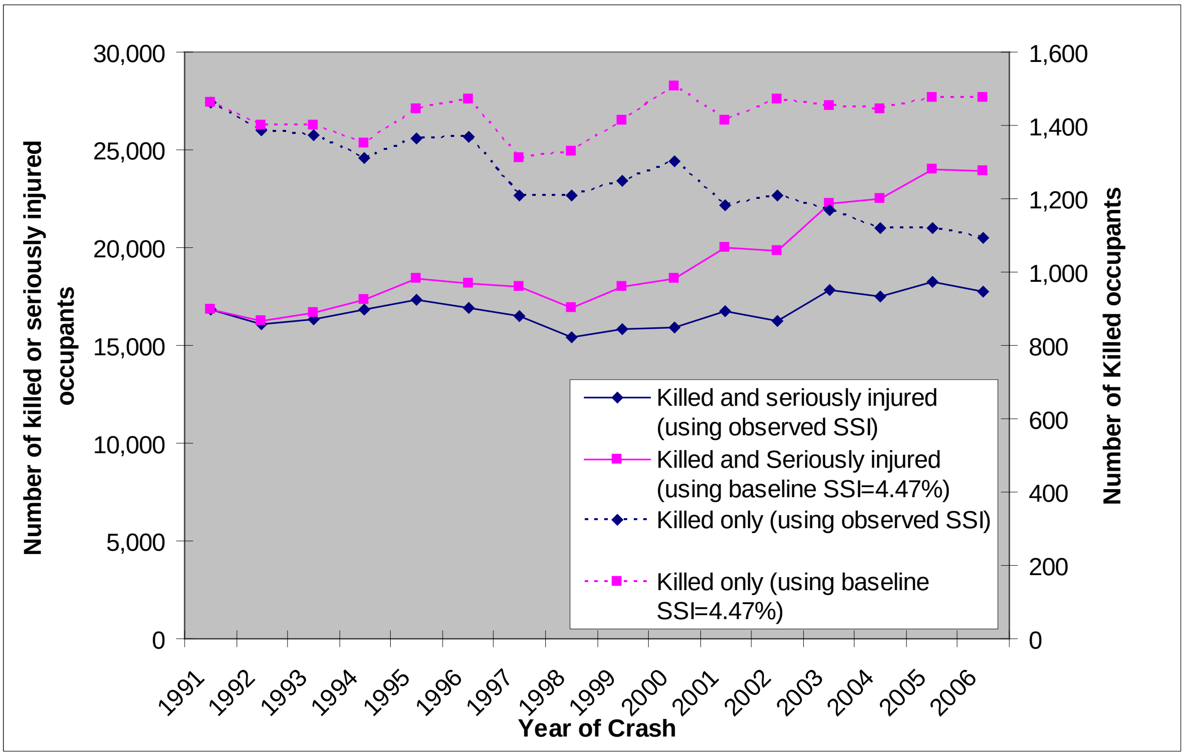
After calculating the average the crashworthiness rating within each crash year, the number of occupants of passenger vehicles seriously injured or killed in Australia and New Zealand for each year in the period 1991-2006 was estimated. In order to estimate the number of occupants seriously injured for each year several assumptions had to be made as the required data were not available in some jurisdictions. These assumptions have been explained in detail in the methodology section.

Once the annual number of seriously injured or killed occupants were estimated for each year in the period 1991-2006, it was possible to estimate how many serious or fatal injuries were prevented due to annual reductions in the secondary safety index. This was done by defining a baseline secondary safety index. In this report, the baseline secondary safety index was defined as being equal to the secondary safety index observed for the fleet in 1991. The baseline secondary safety index could then be used to estimate how many occupants would have been seriously injured or killed in the period 1991-2006 if the secondary safety of vehicles in the fleet had not improved since 1991.

The difference in the number of occupants seriously injured or killed if the baseline secondary safety index was assumed compared to the number derived from actual injury data for the period 1991-2006 was then compared for Australia only, for New Zealand only and for Australia and New Zealand combined. Comparisons were also made for each of the five Australian jurisdictions for which police-reported crash data were available.

In 1991 the average crashworthiness of Australian passenger vehicles was estimated to be 4.5%. This risk of serious injury or death decreased steadily over the next fifteen years so that by 2006 the average crashworthiness of the Australian fleet was estimated to be 3.3%. It was also found that the secondary safety index did not vary greatly when disaggregated across the five Australian jurisdictions.

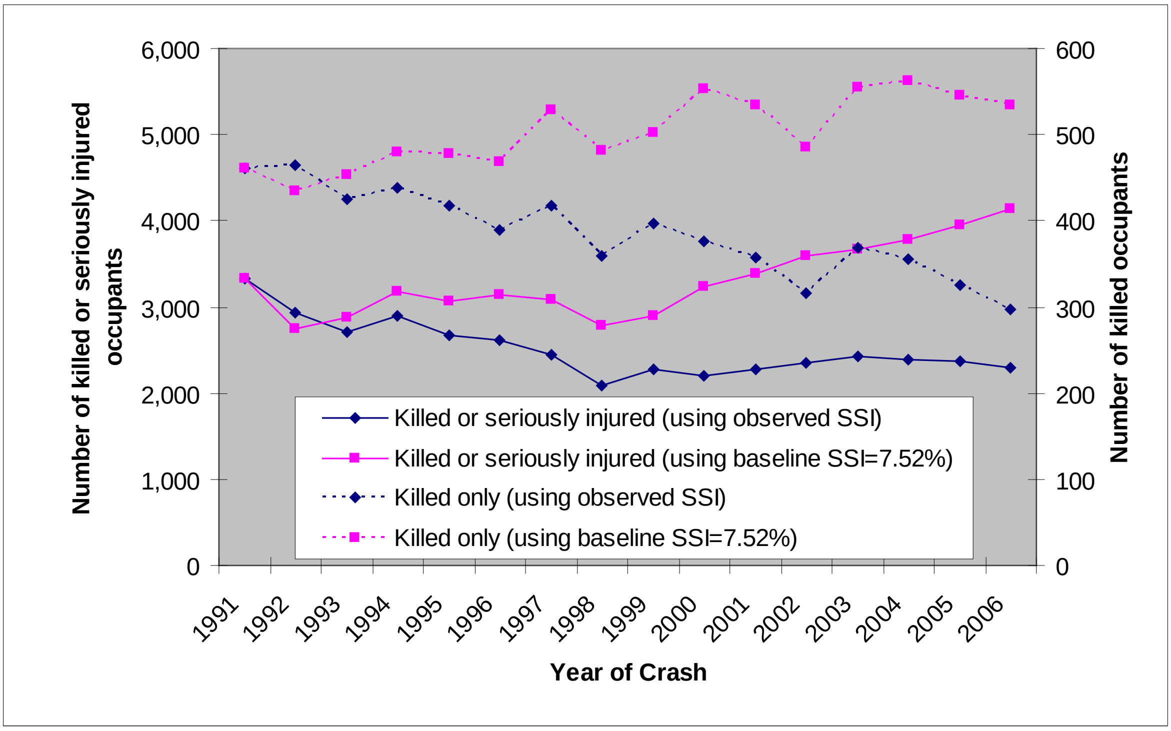
The figure below shows the difference between estimates of the number of occupants killed or seriously injured in Australia derived using the baseline secondary safety index compared to when the observed secondary safety index was used. As the observed secondary safety index improves with each passing year, there is an increase in the difference between the observed number of occupants killed or seriously injured and the number estimated if there were no improvements to secondary safety. Over the period 1991-2006 about 39,000 additional cases of occupants being seriously injured or killed would be expected if the secondary safety of the fleet had not improved since 1991, which is 14.6% higher than the total number of serious injuries and fatalities observed during that period. When considering fatalities in isolation, the improved secondary safety of the Australian fleet has saved an estimated 2,700 lives in the period 1991-2006.



Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), Australia, 1991-2006

The New Zealand passenger vehicle fleet differs to the Australian fleet in that a relatively high proportion of vehicles in New Zealand are used cars that were imported into the fleet from overseas, mainly from Japan. This is probably part of the reason why the average crashworthiness of the New Zealand fleet actually increased some years while the secondary safety index for the Australian fleet improved each year in the period 1991-2006. In 1991, the average crashworthiness of the New Zealand fleet was estimated to be about 7.5% and a year later it rose to 8.1%. However, in general, the secondary safety index for New Zealand decreased over the period 1991-2006. By 2006 the secondary safety of the New Zealand fleet was estimated to be 4.2%.

The figure below shows the annual number of occupants killed or seriously injured in New Zealand if the secondary safety index remained at 1991 levels (i.e. 7.5%) compared to the observed number killed or seriously injured. Improvements to the secondary safety of the New Zealand fleet since 1991 meant that approximately 12,600 fewer occupants were killed or seriously injured in the period 1991-2006 than would have been expected if the secondary safety index remained at 1991 levels during this time. This means that if the secondary safety of the New Zealand fleet had not improved since 1991, the total number of serious injuries and fatalities observed since 1991 would be 31.3% higher than that actually observed. When considering fatalities alone, the improved secondary safety of the New Zealand fleet over the period 1991-2006 was estimated to have saved about 1,900 lives.

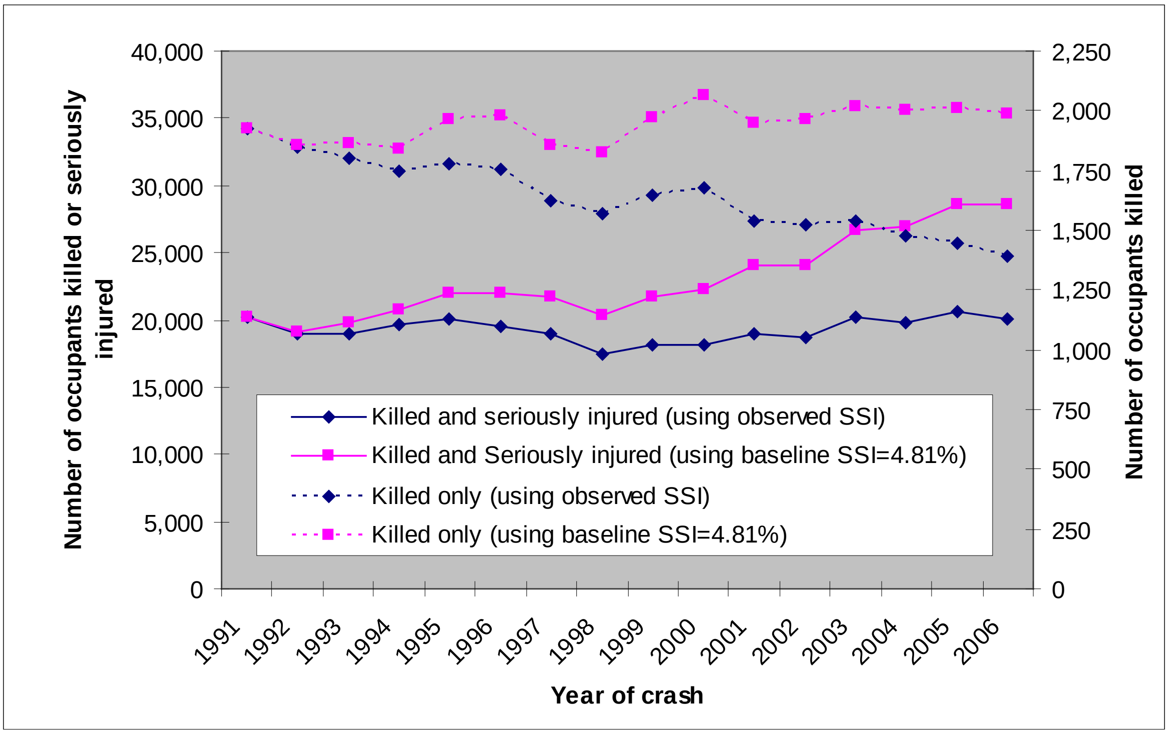


Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (7.52%), New Zealand, 1991-2006

It was also found that the secondary safety index for Australia and New Zealand combined was very similar to that derived using Australian data only. In 1991, the average crashworthiness of the two countries' fleets was estimated to be 4.8%, with this decreasing to 3.4% by 2006. The figure on the next page shows the annual number of occupants killed or seriously injured in New Zealand and Australia if the secondary safety index remained at 1991 levels (i.e. 4.8%) compared to the number actually observed.

The report also presents results specific to each of the five Australian jurisdictions for which police-reported crash data were available. In order to present such analyses, several assumptions had to be made. These assumptions are discussed in the relevant sections of the report. It was found that, in general, the level of savings observed in a jurisdiction was dependent on the size of the crash fleet. Therefore, improvements to secondary safety resulted in more serious injuries being prevented in larger fleets such as New South Wales and Victoria than smaller fleets such as South Australia.

Several issues concerning the use of "serious injuries" to measure the performance of road safety countermeasures are explored in the discussion section of the report. Possible ways of overcoming the problems of obtaining a consistent definition of serious injury are raised with the hope that these could be explored further in the future.



Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (4.81%), Australia and New Zealand, 1991-2006

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Estimation of the effect of improved average secondary safety of the passenger vehicle fleet on annual counts of serious injury for Australia and New Zealand: 1991-2006

1. BACKGROUND

When defining and evaluating their road strategies governments set targets for reducing the burden of injury due to motor vehicle crashes. For example the New Zealand Ministry of Transport's (2003) road safety strategy aims to reduce the annual number of deaths to 300 and the annual number of hospitalisations to 4,500 by 2010, while the Australian Transport Council (2002) set a target of a 40% reduction in fatalities per 100,000 population by 2010. In order to reach their targets, Governments have traditionally focused on three theatres of action: improving the safety of the road environment; improving the behaviour of road users; and improving the safety of vehicles. Efforts to improve the safety of vehicles can, in general, be categorised into three main groups: making vehicles less aggressive to other road users; making vehicles less likely to be involved in crashes; and improving the level of occupant protection offered by vehicles so that the risk of an occupant being injured when involved in a crash is reduced.

Examples of efforts to improve the safety of vehicles include recent evaluations of technologies that help drivers avoid dangerous situations, such as Electronic Stability Control and Anti-lock Braking (Scully & Newstead, 2008; Burton, Delaney, Newstead, Logan & Fildes, 2004). This has encouraged governments to set safety goals that can be achieved if such technologies can be introduced as quickly as possible to the passenger vehicle fleet. Another area of interest is the increasing polarisation of the vehicle fleet in terms of vehicle mass, which Newstead, Delaney, Watson & Cameron (2004) noted is occurring in Australia as well as other jurisdictions. This has lead to a greater emphasis on designing vehicles that are less aggressive toward lighter vehicles. For example, a recent status report from the Insurance Institute for Highway Safety (2008) explained that in 2003, car manufacturers committed to designing the front ends of four wheel drives and pickups (truck-based utilities) that are more compatible with the front ends of smaller passenger cars and that this had resulted in reduced risk of death for occupants of vehicles struck by larger vehicles that were compliant with the compatibility commitments.

However in the last two decades, the most-sustained efforts in the field of vehicle safety have been improving the level of protection that passenger vehicles offer to their occupants. In 1994, Cameron, Finch & Le developed a complex statistical analysis procedure to rate the secondary safety of passenger vehicles in the Australian fleet. These ratings measured the risk of a driver being seriously injured given involvement in a police-reported crash. The methodology used to create these ratings was such that the estimates of risk were, as far as possible, free of the effect of non-vehicle factors. The original ratings used data from real crashes occurring in Victoria and New South Wales. Since 1994, data from South Australia, Western Australia, Queensland and New Zealand have also been used to create the Used Car Safety Ratings.

As well as providing consumers with a guide for determining the safety of different vehicles when purchasing a car, the ratings have also been used to track the effect of various safety improvements. For example, recent updates of the ratings have compared the secondary safety of vehicles manufactured in different years. This demonstrates how, in general, newer vehicles offer better protection than older vehicles. Other studies have used the Used Car Safety Rating data to evaluate the effectiveness of particular technologies such as Electronic Stablity Control (Scully & Newstead, 2008) and Anti-lock Braking (Burton et al., 2004). Although such studies quantify the improved safety of new vehicles and new technologies, they are not useful in determining how vehicle safety advances have improved the absolute safety of the entire fleet. This is because they do not take into account how long older vehicles remain in the fleet.

Keall & Newstead (2008) developed an index that rated the average secondary safety performance for the New Zealand vehicle fleet over time. This allowed quantification of the effect of vehicle safety improvements on the average safety of the entire fleet. As Keall & Newstead (2008) explained, this index could be used to increase understanding of the importance of occupant protection amongst the general public as well as policy makers. This would allow policy makers to set achievable safety targets in their road safety strategies.

The aim of the present analysis is similar to that of Keall & Newstead (2008), except the present analysis has a broader scope. Keall & Newstead (2008) demonstrated that a secondary safety index which measures the average crashworthiness of a fleet over time can be developed using police-reported crash data from New Zealand. The aim of the present report is to develop an index of the average secondary safety of the passenger vehicle fleet in Australia and New Zealand and then quantify what effect improvements in secondary safety have had on the number of people seriously injured or killed due to road crashes. The report will be limited to examining the effect of improvements to secondary safety that have occurred since 1991, as this was the earliest year for which the required crash data could be obtained.

The following section describes the crash data used to achieve this aim as well as describing the methodology used. The methodology is similar to that developed by Keall & Newstead (2008). Results are presented for Australia and New Zealand separately as well as for both countries combined. Relevant findings are explored in the discussion section.

2. METHODS

This study quantifies what effect improvements in secondary safety have had on the number of people seriously injured or killed due to road crashes in Australia and New Zealand in the period 1991 to 2006. In order to do this, the following three-stage methodology was devised:

1. Define a metric of secondary safety;
2. Define an index of secondary safety by calculating the average value of the secondary safety metric for vehicles in the fleet for each year in the period 1991-2006;
3. Estimate the effect of changes to the secondary safety index on the annual number of occupants seriously injured or killed.

In a similar study by Keall & Newstead (2008), who defined a benchmark tool for measuring the secondary safety for the New Zealand passenger vehicle fleet, registration data was used to define an index of secondary safety. Keall & Newstead (2008) also defined an index that used crash data. As explained by Keall & Newstead (2008), suitable registration data from New Zealand was only available from 2000 onwards. So the index that was defined using crash data could be applied to the fleet for years prior to 2000, while the index defined using registration data could only be applied for the period from 2000 onwards. However, Keall & Newstead (2008) found that the index derived using crash data and the index derived using registration data showed similar annual changes in secondary safety for common crash years (2000 to 2007).

In the present analysis it was necessary to use crash data to define a secondary safety index because none of the Australian jurisdictions could supply registration data for years prior to 2000. Keall and Newstead's (2008) finding that using crash data yielded a similar index of secondary safety to that defined using registration data validates the approach used in the present analysis.

The following section describes the crash data used to define the metric of secondary safety defined in the first stage of the methodology. Crash data from five Australian states (New South Wales, Queensland, South Australia, Victoria and Western Australia) and New Zealand were used to define the metric.

2.1. Crash data

The crash data used to define an index of secondary safety was the same as that used in the 2008 update of the Vehicle Safety Ratings by Newstead, Watson & Cameron (2008a) except that the present report only used data from vehicles crashing in the period 1991-2006 (the 2008 update of the Vehicle Safety Ratings using data from 1987 onwards).

Newstead, Watson & Cameron (2008a) did not rate the crashworthiness of specific models of vehicles that were manufactured prior to 1982. This meant that when defining the secondary safety index, data for vehicles manufactured prior to 1982 were analysed separately (and in a different way) to data for more-recently manufactured vehicles. Section 2.2 explains the way crash data for vehicles manufactured in these two periods were used to define the secondary safety index. However, the following paragraphs briefly describe the methods for selecting appropriate data from those that were available for each jurisdiction.

2.1.1. Victoria

To produce the 2008 update of their Vehicle Safety Ratings, Newstead, Watson & Cameron (2008a) used data of police reported crashes from six jurisdictions, including Victoria. Since crashes in Victoria are in general only reported to police if a person is injured or killed, the Victoria crash data only includes vehicles involved in a crash in which a road user was injured; property damage only crashes are in general not included. This meant that the Victorian crash data were not suitable for estimating injury risk, but the data were used by Newstead, Watson & Cameron (2008a) to estimate the risk that an injured driver was seriously injured.

Even though the only Victorian crash records that Newstead, Watson & Cameron (2008a) used in the 2008 update of the Vehicle Safety Ratings, were records from vehicles in which the driver was injured, the present report has used Victorian records for both injured and uninjured drivers to define a secondary safety index for vehicles manufactured from 1964 to 2006. This is because the crash data used to define the secondary safety index is supposed to approximate the New Zealand and Australian passenger vehicle fleets. The analysis sample will better approximate the Australasian fleet if crash data from as wide a range of crashes as possible are used. For Victoria, data from all passenger vehicles involved in injury crashes represent a broader sample of crashes in Victoria than just records of vehicles in which the driver was injured.

As previously mentioned, this analysis only used data from passenger vehicles crashed in the period 1991 to 2006. The data source used to provide records of crashed vehicles manufactured in the period 1964 to 1981 was the same as the data source used by Newstead, Watson & Cameron (2008a) to estimate the average crashworthiness of vehicles grouped by year of manufacture for vehicles manufactured from 1964 to 2006.

Newstead, Watson & Cameron (2008a) used a different set of data to estimate the crashworthiness of vehicles grouped by year of manufacture to that used to rate the crashworthiness of individual models of passenger vehicles. The reason Newstead, Watson & Cameron (2008a) used a different data source to estimate the average crashworthiness of vehicles grouped by year of manufacture was that some records that were not suitable for the analysis of different makes and models could be used to estimate average crashworthiness by year of manufacture. For each jurisdiction, Newstead, Watson & Cameron (2008a) referred to the dataset used to estimate average crashworthiness for each year of manufacture as the dataset of *involved drivers*. This term will also be used in the present report when referring to the dataset used to approximate the sample of vehicles manufactured from 1964 to 1981.

Unfortunately, the Victorian involved drivers dataset did not contain records of crashes occurring in the years 1991 to 1998. Therefore, a representative sample of the Victorian crash fleet could only be gained for crash years 1999 to 2006. Of the 188,730 records in the involved drivers dataset of crashes occurring in Victoria in the period 1999 to 2006, 16,360 were vehicles manufactured from 1964 to 1981. These 16,360 records were used to approximate the sample of vehicles manufactured in the period 1964 to 1981 that were involved in crashes in Victoria in the period 1999 to 2006.

Newstead, Watson & Cameron (2008a) used different data to produce crashworthiness estimates for different models of passenger vehicles in the 2008 update of the Vehicle Safety

Ratings. In the present report, these data will be referred to as the *crashworthiness* data. Each record in the crashworthiness data contained additional make and model information to that available in the involved driver data. This additional information was only available for vehicles manufactured from 1982 to 2006, so Newstead, Watson & Cameron (2008a) only rated the crashworthiness of models of vehicles manufactured in the period 1982 to 2006.

For crashes occurring in Victoria in the period 1991-2006, the crashworthiness dataset contained 199,959 records of vehicles manufactured between 1982 and 2006. However, because the involved drivers dataset did not contain data on vehicles manufactured before 1982 that crashed in the period 1991-1998, a representative sample of the Victorian crash fleet could only be derived for the years 1999-2006. Of the 199,959 records available for use in the crashworthiness dataset, 172,370 occurred in the period 1999 to 2006.

When the 16,360 records of vehicles manufactured prior to 1982 from the involved drivers dataset were added to 172,370 records of vehicles manufactured from 1982 to 2006 in the crashworthiness dataset, the total number of records used to create a representative sample of the Victorian fleet for the period 1999-2006 was 188,730.

2.1.2. New South Wales

An important difference between the Victorian and New South Wales (NSW) crash data used by Newstead, Watson & Cameron (2008a) was that the police-reported crash data from NSW included records of property damage only crashes in which a vehicle had to be towed from the scene. This meant that Newstead, Watson & Cameron (2008a) could use the NSW crash data to estimate the risk of driver injury in cars sufficiently damaged to require towing. Furthermore, the NSW crash data represented a broader sample of crashes than that available from the Victorian crash data (which only contained records of vehicles involved in crashes resulting in injury). Therefore, the NSW crash data are a more representative sample of the NSW fleet than the analogous sample derived for the Victorian fleet.

As mentioned in the previous section in which Victorian crash data were discussed, Newstead, Watson & Cameron (2008a) used a dataset of *involved drivers* to estimate the average crashworthiness by year of manufacture, while a separate *crashworthiness* dataset was used to rate the crashworthiness of different models of vehicles manufactured in the period 1982-2006.

Unlike crashes in Victoria, the involved drivers dataset contained records of vehicles crashed in New South Wales for each year in the period 1991-2006. Of the 1,157,439 vehicles in the involved drivers dataset that crashed in New South Wales in the period 1991-2006, 166,802 were manufactured in the period 1964 to 1981. Similarly, the crashworthiness dataset contained records of 1,051,632 vehicles that were crashed in New South Wales in the period 1991-2006, of which 994,267 were manufactured in the period 1982-2006. To approximate the New South Wales passenger vehicle fleet for each year in the period 1991-2006, the 166,802 records of vehicles manufactured from 1964 to 1981 were added to the 994,267 vehicles that were manufactured from 1982 to 2006. Therefore, 1,161,069 records of vehicles crashed in New South Wales were used to approximate the New South Wales passenger vehicle fleet for each year from 1991 to 2006.

2.1.3. Queensland

As described in Newstead, Watson & Cameron (2008a), Queensland Transport supplied records of 352,638 light passenger vehicles that were involved in police-reported crashes in the period 1991-2006. Newstead, Watson & Cameron (2008a) described how for years 1997 and 1998 there was difficulty in matching crash records with registration data. Therefore, for these years there was a lower-than-expected number of vehicles with valid year of manufacture values. This meant that Queensland data could not be used to approximate the passenger vehicle fleet in Australia for both these years. When data for vehicles crashed in 1997 and 1998 were excluded from the Queensland crashworthiness dataset, 308,035 vehicles remained. These data included data of vehicles involved in crashes in which road users were injured as well as crashes that resulted in a vehicle being towed away. Therefore, like NSW, Queensland crash data could be used to estimate both the risk of a driver being injured given involvement in a police-reported crash as well as the risk that an injured driver was seriously injured.

Of the 308,035 vehicles in the Queensland crashworthiness datasete that crashed in the periods 1991-1996 or 1999-2006, 264,174 were identified as being manufactured from 1982 to 2006. Data for these vehicles were used to approximate the composition of the Queensland light passenger vehicle fleet for vehicles manufactured since 1982.

For vehicles manufactured prior to 1982, records from the involved drivers dataset for Queensland showed that 51,681 of the 312,617 vehicles were manufactured from 1964 to 1981. Due to the previously-mentioned difficulties in accessing registration data for vehicles crashed in the period 1997-1998, these 312,617 records did not include vehicles crashed in either 1997 or 1998. Therefore, adding the 51,681 records of pre-1982 vehicles to the 264,174 records of vehicles manufactured from 1982 to 2006 resulted in approximations of the fleet distributions in Queensland for each year in the period 1991-2006 with the exception of the period 1997-1998. Therefore, the total number of vehicles used to estimate the Queensland fleet was 315,855 records.

2.1.4. South Australia

The Department of Transport, Energy and Infrastructure provided Newstead, Watson & Cameron (2008a) with records of vehicles involved in crashes that resulted in either a road user being killed or injured; a vehicle being towed away; or a total property damage exceeding a threshold value. For crashes occurring since 1st July 2003 the threshold value was $3,000; previously the threshold for the inclusion of a property damage only crash was $1,000. Therefore, crash records from South Australia were used by Newstead, Watson & Cameron (2008a) to estimate the risk of a driver being injured as well as the risk of an injured driver being seriously injured. However, crash data from South Australia were only available for vehicles crashing in the period 1995-2006.

The crashworthiness dataset that was supplied by the Department of Transport, Energy and Infrastructure to rate the crashworthiness of individual makes and models contained records of 576,069 vehicles that were manufactured in the period 1982-2006. The involved drivers dataset used to estimate the average crashworthiness of vehicles grouped by year of manufacture contained records for 666,948 vehicles, 116,036 of which were identified as being manufactured in the period 1964-1981. Aggregating these two datasets meant that records of 692,105 vehicles crashed in South Australia in the period 1995 to 2006 were used to approximate the passenger vehicle fleet for this period.

2.1.5. Western Australia

The Western Australian Department of Main Roads provided Newstead, Watson & Cameron (2008a) with records of vehicles involved in crashes in which a road user was killed or injured or in which the property damage resulting from the crash exceeded $1,000. As these data included information on property damage only crashes as well as injury crashes, the Western Australian crash data could be used to estimate the injury risk and the injury severity components of the crashworthiness ratings published by Newstead, Watson & Cameron (2008a).

As with data from other jurisdictions, Newstead, Watson & Cameron (2008a) used one set of crash data from Western Australia to rate the crashworthiness of different models of vehicles manufactured since 1982 (i.e. the crashworthiness dataset) and a different dataset to rate average crashworthiness by year of manufacture for vehicles manufactured since 1964 (the involved drivers dataset).

For Western Australia, the crashworthiness dataset contained records of 878,766 vehicles crashed in the period 1991 to 2006, 668,432 of which could be identified as being manufactured in the period 1982-2006. The involved drivers dataset contained 788,689 records of vehicles crashed in the same period, but only 120,096 were found to have been manufactured from 1964 to 1981. Therefore, data from 788,528 vehicles crashed in Western Australia in the period 1991-2006 were used to approximate the passenger vehicle fleet for each year in this period.

2.1.6. New Zealand

Newstead, Watson & Cameron (2008b) described how crash and registration data from New Zealand were used to estimate the average crashworthiness of New Zealand vehicles by year of manufacture. These data were also used in the current report to approximate the passenger vehicle fleet in New Zealand for each year in the period 1991-2006. The crash data supplied by Land Transport New Zealand included data on vehicles involved in police-reported crashes. However, as it is not mandatory for a non-injury crash to be reported to police, Newstead, Watson & Cameron (2008b) only used New Zealand crash data to estimate the injury severity component when rating the crashworthiness of different makes and models.

As explained by Newstead, Watson & Cameron (2008b), the dataset used to estimate crashworthiness by year of manufacture for New Zealand contained records of 200,728 light passenger vehicles involved in police-reported crashes in the period 1991 to 2006. Of these vehicles, 35,549 were manufactured between 1964 and 1981 while 165,175 were manufactured from 1982 to 2006. Therefore, a total of 200,724 vehicles involved in police-reported crashes were used to approximate the New Zealand light passenger vehicle fleet for each year in the period 1991-2006.

2.1.7. Combining data from six jurisdictions

The preceding paragraphs describe a sample of crashed vehicles that can be used to approximate the light passenger vehicle fleet for each year in period 1991-2006 for five Australian states and New Zealand. When the data from each jurisdiction were combined, they collectively represented an approximation of the Australasian light passenger vehicle fleet for each year in the period 1991-2006. For some jurisdictions, crash data from some years were not available (e.g. 1997-1998 for Queensland). This meant that aggregated fleet numbers did not increase from year to year in a linear fashion (see Figure 1). However these data could still be used to estimate the average crashworthiness of the light passenger vehicle fleet in Australasia for each year in the period 1991-2006. When the crashed vehicle data were aggregated across all six jurisdictions, the total number of vehicle records used to estimate the average crashworthiness of the fleet was 3,347,011, while if only data from Australian jurisdictions were included, records of 3,146,287 crashed vehicles were used to estimate the light passenger vehicle fleet for the period 1991-2006.

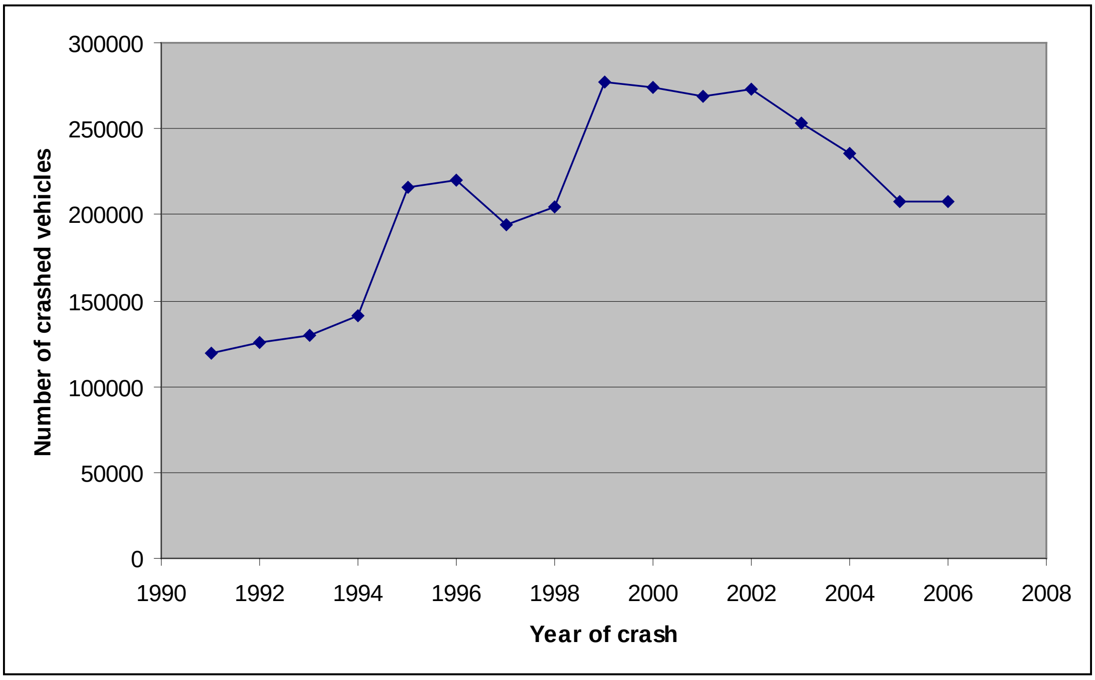

Figure 1: Aggregated number of crashed vehicles manufactured from 1964 to 2006 for five Australian states and New Zealand

2.2. Defining a metric of secondary safety

The secondary safety metric used in this report is based on the most-recent Vehicle Safety Ratings (Newstead, Watson & Cameron, 2008a) which rated the crashworthiness of different models of light passenger vehicles. Newstead, Watson & Cameron (2008a) defined *crashworthiness* as "a measure of the risk of death or serious injury to a driver of that vehicle when it is involved in a crash" (p.2). Crashworthiness was also used by Keall & Newstead (2008) when they analysed changes in the secondary safety of the New Zealand vehicle fleet. Although the measure of crashworthiness derived by Newstead, Watson & Cameron (2008a) was only an estimate of each vehicle's relative secondary safety and the accuracy of each rating was indicated by confidence limits, Keall & Newstead (2008a) demonstrated how the point estimates of individual ratings could be used to define a robust index of secondary safety. Therefore, like Keall & Newstead (2008a), the present report used the point-estimates of crashworthiness ratings from Newstead, Watson & Cameron (2008a) to derive the metric of secondary safety which could then be used to drive an index of secondary safety (see section 2.3).

Newstead, Watson & Cameron (2008a) estimated crashworthiness by taking the product of two risk estimates: the risk of injury for drivers involved in police-reported crashes; and the risk that an injured driver is fatally or seriously injured. Newstead, Watson & Cameron (2008a) measured crashworthiness using injury outcomes of drivers only because some jurisdictions, such as New South Wales, do not record the age and sex of uninjured passengers and such data are required by the statistical models used to estimate crashworthiness. However, if it is assumed that the relative protection that a vehicle offers to its driver is related to the relative level of protection it offers to its passengers, the crashworthiness measure can be considered to be a measure of the ability of a vehicle to protect its occupants from serious injury or death when involved in a crash.

A complex statistical analysis process developed by Cameron, Finch & Le (1994) was used by Newstead, Watson & Cameron (2008a) to adjust for the biasing influence of non-vehicle factors such as driver age and sex. This enabled 406 distinct models of vehicles to be given crashworthiness ratings and for ratings to be given for different groups of vehicles defined by market group and year of manufacture. Models of vehicles manufactured prior to 1982 were not given crashworthiness ratings but records of these vehicles were used when rating the crashworthiness of vehicles grouped by market group and year of manufacture. Newstead, Watson & Cameron (2008a) did not provide ratings for some post-1982 models because the estimates of crashworthiness for these models were unreliable due to there only being a small number of these types of vehicles in the crash datasets.

To define an index of secondary safety for the Australasian vehicle fleet using the crashworthiness metric, each vehicle in the dataset of crashed vehicles from the six jurisdictions were given a crashworthiness rating. The average rating within each crash year was then estimated. For each record, the crashworthiness rating was assigned in one of three ways, depending on whether a model-specific rating was available for the model of the vehicle that was the subject of the record.

The first way of assigning a crashworthiness rating to a vehicle record was to identify the make and model of the vehicle and assign the point-estimate of the rating that Newstead, Watson & Cameron (2008a) had derived for that particular make and model. This method could only be used to assign a crashworthiness rating for vehicles manufactured in the period 1982-2006. Model categories were defined by Newstead et al. (2008a) so that each is as homogeneous as possible with respect to secondary safety performance.

In some cases, a record of a crashed vehicle could not be placed into one of the 406 model categories for which a reliable rating was available. This could occur either because the record contained insufficient information to properly identify the model of the vehicle, or because the record was categorised into a model grouping for which a robust crashworthiness rating had not yet been derived due to only a small quantity of crash data being available for the particular model. In both these cases, the year of manufacture and the market category values were used to assign a crashworthiness rating. Crashworthiness estimates by year of manufacture for each market category were taken from Appendix 9 of Newstead, Watson & Cameron (2008a). However, if the market category of the vehicle was not known, the year of manufacture alone was used to assign a crashworthiness rating (see Appendix 8 of Newstead, Watson & Cameron, 2008a).

Table 1 describes how crashworthiness ratings were defined amongst the sample of crashed vehicles used to create an Australasian index of secondary safety. Results have been disaggregated by jurisdiction. The model of the crashed vehicle was used to determine the crashworthiness metric of a greater proportion of vehicles from NSW, Queensland and Western Australia than for vehicles from Victorian, New Zealand and South Australia. Differences between jurisdictions in the way the crashworthiness metric was defined are most probably due to differences in the level of detail provided in the police-reported crash databases for each jurisdiction.

Table 1: Distribution of the method used to assign crashworthiness ratings by jurisdiction for vehicles manufactured since 1964 that crashed in the period 1991-2006

Data Source	Model		Market Group & Y.O.M		Y.O.M. only		Total	
	N	%	N	%	N	%	N	%
NSW	703,426	60.6	62,781	5.4	394,862	34.0	1,161,069	100
VIC	87,488	46.4	8,505	4.5	92,737	49.1	188,730	100
QLD	191,844	60.7	17,661	5.6	106,350	33.7	315,855	100
WA	523,252	66.4	43,537	5.5	221,739	28.1	788,528	100
SA	323,621	46.8	34,494	5.0	333,990	48.3	692,105	100
NZ	72,701	36.2	23,322	11.6	104,701	52.2	200,724	100
Total	1,902,332	56.8	190,300	5.7	1,254,379	37.5	3,347,011	100

For New Zealand vehicles, the way the crashworthiness metric was defined in the present report is slightly different to the way it was defined by Keall & Newstead (2008). The latter study also used EuroNCAP results and the gross vehicle weight of crashed vehicles to define a secondary safety value to each record in the crash database. This is one of the reasons why the distribution for New Zealand in Table 1 differs to the analogous table from Keall & Newstead (2008). Another reason is that Keall & Newstead (2008) only showed the distribution of the method used to define the crashworthiness metric for crashed vehicles manufactured from 1993 onwards, while Table 1 of the present report includes crashed vehicles manufactured from 1964 onwards.

2.2.1 Defining a metric for New Zealand based on year of manufacture

For New Zealand crashed vehicle records in which it was not possible to assign crashworthiness based on the model of the vehicle or the market group and year of manufacture, it was necessary to assign the crashworthiness of New Zealand vehicles manufactured in the same year. Table 1 shows that 72,701 of the 200,724 (36.2%) records of vehicles crashed in New Zealand had a crashworthiness estimate assigned based on year of manufacture only. In these cases, the crashworthiness ratings by year of manufacture were taken from the supplement to the 2008 update of the Used Car Safety Ratings Report (Newstead, Watson & Cameron, 2008b). Newstead, Watson & Cameron (2008b) explained that it was necessary to provide separate estimates of crashworthiness by year of manufacture for Australia and New Zealand. This was because trends in vehicle crashworthiness by year of manufacture depend on the composition of the vehicle fleet. New Zealand's program of importing used vehicles from overseas means that the mix of vehicles in the New Zealand fleet is different to the Australian fleet. This is true even when comparisons are restricted to vehicles of a particular year of manufacture. However, as explained below, it is difficult to quantify this difference for each year of manufacture.

The reason it is difficult to quantify the differences between Australian and New Zealand estimates of crashworthiness by year of manufacture is that as explained by Newstead, Watson & Cameron (2008b), the crashworthiness by year of manufacture ratings for the Australian fleet were estimated using data from police-reported crashes, which included crashes that did not result in injury. However, because the reporting coverage of non-injury crashes in New Zealand is not clear, the New Zealand crashworthiness by year of manufacture ratings were derived only using data from crashes that resulted in injury. This meant that Newstead, Watson & Cameron's (2008b) average crashworthiness estimates for New Zealand vehicles of a particular year of manufacture represent the risk that a driver of a vehicle manufactured in a particular year is seriously injured given the driver of the vehicle that they collided with was also injured. By comparison, for Australia, the crashworthiness by year of manufacture ratings derived by Newstead, Watson & Cameron (2008a) represent the risk that the driver of the vehicle manufactured in the particular year is seriously injured when involved in a police-reported crash, irrespective of the injury status of other road users involved in the crash. This explains why, as shown in Figure 2, the crashworthiness ratings by year of manufacture for New Zealand vehicles (see pink data points) were greater than that of derived for comparable years using Australian data (see blue data points). Therefore, although the crashworthiness by year of manufacture ratings derived by Newstead, Watson & Cameron (2008b) are effective in representing relative changes in crashworthiness with respect to year of manufacture within the New Zealand fleet, they must be adjusted before they can be used to compare New Zealand crashworthiness trends to Australian trends

In the present report the crashworthiness by year of manufacture estimates for New Zealand were adjusted so that they could be compared to Australian crashworthiness estimates by assuming that the average level of secondary safety of late-model vehicles driven in New Zealand would be similar to that for recently manufactured vehicles driven in the Australian fleet. As the secondary safety standards of new vehicles available for purchase in New Zealand are similar to that of new vehicles available in Australia, this assumption is likely to be true. Therefore, as the crashworthiness by year of manufacture trends derived using New Zealand injury data offer a good indication of the relative differences in crashworthiness by year of manufacture within the New Zealand fleet, estimates for New Zealand vehicles can be scaled to estimates for the Australian fleet by shifting the New Zealand year of manufacture estimates by the difference between Australian and New Zealand crashworthiness estimates for vehicles belonging to a recent model year. In the present report it has been assumed that the average level of secondary safety of vehicles in the New Zealand fleet that were manufactured in 2004 would be approximately equal in vehicles in the Australian fleet that were manufactured in the same year.

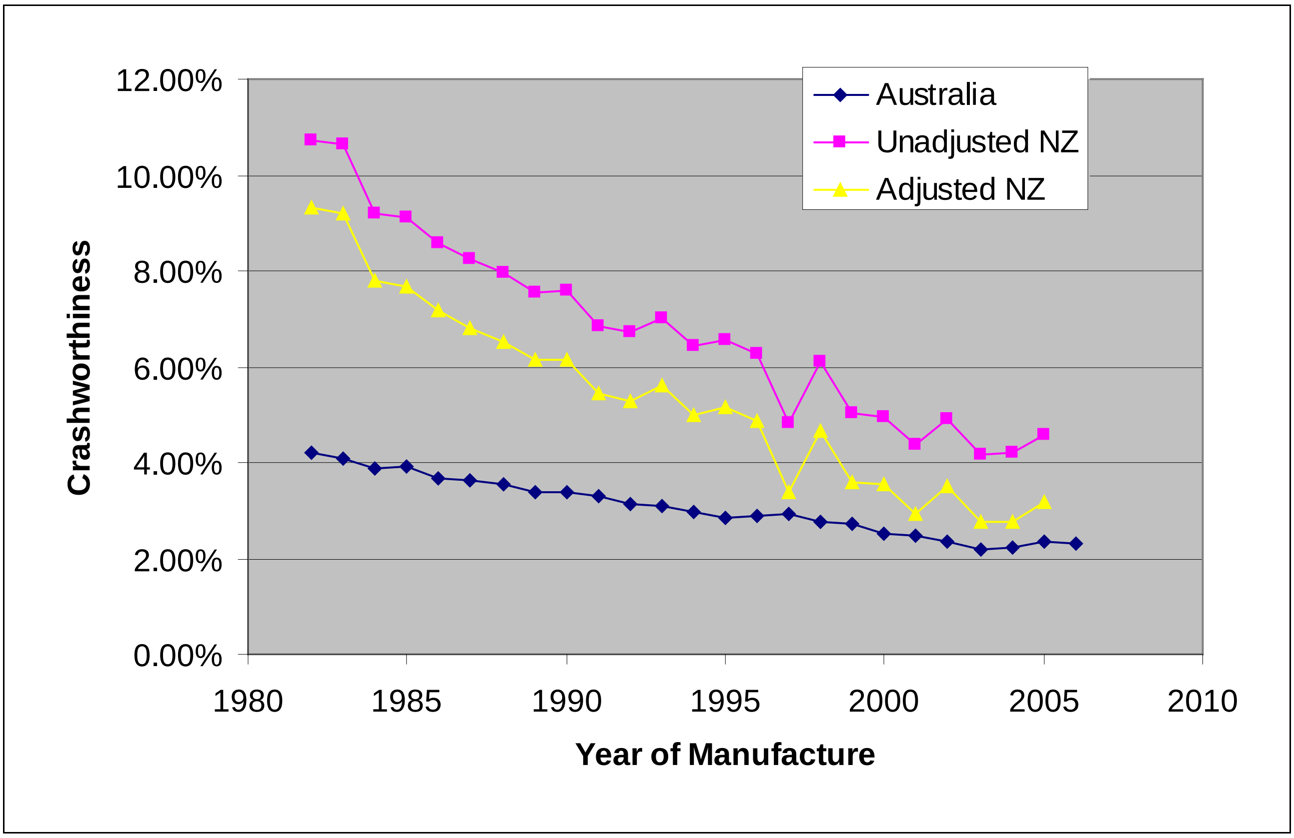

Figure 1: Average crashworthiness of vehicles driven by young drivers by year of manufacture for Australia, New Zealand (unadjusted) and New Zealand where adjustments have been made to account for the unavailability of reliable non-injury crash data

However it is also necessary for the adjustment described in the previous paragraph to take into account differences in the risk of serious injury between Australia and New Zealand. It is likely that the risk of serious injury given involvement in a crash is different for New Zealand when compared with Australia. This is because the distribution of the types of crashes that occur in New Zealand is likely to be different to the distribution of the types of crashes that occur in Australia. However, it is difficult to quantify the difference in the risk of serious injury between Australia and New Zealand because of differences in how serious injuries are reported between the two jurisdictions. Therefore, for the purposes of the present report, the difference between Australia and New Zealand in the risk of a driver being killed per 100,000 registered vehicles was used to account for differences in overall serious injury risk between the two countries. Using the Used Car Safety Rating data for crashes occurring in 2004 and registration counts available from the Australian Bureau of Statistics (2005) and the New Zealand Ministry of Transport's website[1], it was found that 5.61 drivers were killed per 100,000 passenger vehicle registrations in Australia, compared with 6.95 for New Zealand. Therefore the ratio of driver fatalities per 100,000 driver registrations for New Zealand compared to Australia was approximately 1.24:1. Multiplying the estimate of the average crashworthiness of cars manufactured in 2004 for Australia by 1.24 gives an estimate of the risk of serious injury for New Zealand drivers of vehicles manufactured in 2004 that is not biased by the lack of reliable non-injury data in New Zealand.

[1] http://www.transport.govt.nz/research/Pages/annual-statistics-2005.aspx

Newstead, Watson & Cameron (2008a) estimated that the average crashworthiness of vehicles manufactured in 2004 in the Australian fleet was 2.24%. Multiplying by 1.24 gives an estimate of 2.78% for the risk of serious injury for New Zealand drivers of vehicles manufactured in 2004. Newstead, Watson & Cameron (2008b) estimated that the average crashworthiness of 2004 model vehicles in the New Zealand fleet was 4.20%, which is approximately 1.4 percentage points higher than the corrected estimate of 2.78%. Lowering Newstead, Watson & Cameron's (2008b) New Zealand crashworthiness estimate for each year of manufacture category by 1.4 percentage points will give an estimate of crashworthiness by year of manufacture that can be compared with analogous estimates derived using Australian data.

Therefore, the 72,701 records of vehicles crashes in New Zealand which could not be assigned a crashworthiness estimate based on model identifiers or using market group classification were assigned a crashworthiness estimate equal to the yellow data points presented in Figure 2.

2.3. Defining an index of secondary safety

When each crashed vehicle record had been assigned a crashworthiness rating, the average rating within each crash year was derived. These average crashworthiness ratings are the secondary safety index used in the current report.

The previous section explained how the crash data presented in Section 2.1 were disaggregated into homogenous groups that were given the same crashworthiness rating. As Table 1 demonstrated, most of the vehicles in the crash datasets were categorised using make and model data while other groups were defined using market group and year of manufacture variables and others were defined using year of manufacture data alone. In the present report, C_i is used to refer to the crashworthiness rating assigned to a group of crashed vehicles i. The values of C_i for each group of vehicles i can be found in Appendices 4 (if make and model data were used to assign crashworthiness values for the group), 8 (if year of manufacture and market group values were used) and 9 (year of manufacture values only) of the most-recent update of the Vehicle Safety Ratings (Newstead, Watson & Cameron, 2008a). Therefore, if N_{ijk} represents the number of crashed vehicle records categorised into crashworthiness group i that crashed in jurisdiction j in year k the secondary safety index for jurisdiction j in year k is equal to

$$SSI(j,k) = \frac{\sum_i C_i \times N_{ijk}}{\sum_i N_{ijk}} \qquad \textit{(Eqn.1)}$$

while the secondary safety index across all jurisdictions is equal to

$$SSI(k) = \frac{\sum_j \left(\sum_i C_i \times N_{ijk} \right)}{\sum_j \left(\sum_i N_{ijk} \right)}. \qquad \textit{(Eqn.2)}$$

2.4. Estimating the effect of changes to the secondary safety index on the annual number serious and fatal injuries

The secondary safety index defined in the previous section measures the average secondary safety of a fleet of vehicles. Secondary safety is measured in terms of the risk that a driver is killed or seriously injured given their vehicle is involved in a police-reported crash. In this report, it is assumed that a vehicle offers the same level of secondary safety to the driver of the vehicle as to any other passengers in the vehicle. This assumption allows the secondary safety index to be used to estimate the extent to which changes in secondary safety over the period 1991-2006 have reduced the number of serious injuries and fatalities compared to if the fleet's secondary safety had not improved since 1991. Under this assumption, the number of occupants *involved* in police-reported crashes in jurisdiction j and year k can be expressed as

$$I_{jk} = S_{jk} \big/ SSI(j,k) \qquad \textit{(Eqn.3)}$$

where S_{jk} is the number of occupants observed to be seriously injured or killed jurisdiction j and year k.

The baseline secondary safety index for each jurisdiction was assumed to be the secondary safety index for that jurisdiction in 1991, e.g. the baseline secondary safety index for jurisdiction j will be *SSI(j,1991)*, while the baseline secondary safety index for Australasia will be *SSI(1991)*, each of which can be derived using equations 1 and 2 respectively.

The number of serious injuries that would be expected in jurisdiction j and year k if the serious safety index remained at 1991 baseline levels during the period 1991-2006 is equal to

$$\hat{S}_{jk} = SSI(j,1991) \times I_{jk} \qquad \textit{(Eqn.4)}$$

or, using equaiton 3,

$$\hat{S}_{jk} = S_{jk} \times \left(\frac{SSI(j,1991)}{SSI(j,k)} \right). \qquad \textit{(Eqn.5)}$$

Therefore, estimation of the number of serious or fatal injuries that would be expected without annual reductions in the secondary safety index was achieved by multiplying the observed number of serious injuries and fatalities for each year in the period 1991-2006 by the ratio of the baseline secondary safety index to the secondary safety index estimated for each year. The number of serious or fatal injuries prevented across all jurisdictions can be written as

$$\hat{S}_k = \left(\sum_j S_{jk} \right) \times \left(\frac{SSI(1991)}{SSI(k)} \right). \qquad \textit{(Eqn.6)}$$

In order to use equations 5 and 6 to understand the effect of the improved secondary safety of the light passenger fleet on the number of serious injuries and fatalities, it is necessary to estimate the number of serious injuries and fatalities each year in the period 1991-2006. This in itself is a difficult task, as each jurisdiction has different definitions of what constitutes a serious injury, and some jurisdictions, such as New South Wales, do not distinguish between a minor injury and a serious injury when reporting on road trauma. The reason for this in the case of New South Wales is that in 1998 the Road Traffic Authority became aware of inaccuracies in how injury severity was being recorded. As these inaccuracies could not be rectified, from 1999 onwards, the injury level of road users involved in crashes in NSW was coded as fatal, injured or uninjured.

In the present report, a seriously injured road user has been defined as a road user who is admitted to hospital but did not die as a result of a crash. Even if different jurisdictions also defined serious injury in terms of hospital admissions, the fact that different jurisdictions use different procedures for admitting injured road users who present at hospitals means that there will be differences between jurisdictions in what level of injury constitutes a serious injury. Furthermore, temporal changes in the way patients are admitted to hospital also mean that the definition of serious injury is not likely to be consistent over time. This means that an increase in the number of serious injuries over time may not necessarily indicate a deterioration in road safety but could be because of a change in the way injured road users are treated or a change in the way injury data are collected. Such changes can be difficult to detect if they occur gradually over several years.

The following section describes the process used to estimate the annual numbers of seriously injured and fatally injured road users in Australia. This is followed by a section that describes how annual fatal and serious injury counts were estimated for crashes occurring in New Zealand. Dividing the estimate of the aggregated number of serious injuries and fatalities for each year by the secondary safety index gives an estimate of the number of occupants involved in crashes in the year (irrespective of their injury status). Applying equation 5 (or equation 6) will give an estimate of the number of occupants fatally or seriously injured each year assuming the secondary safety of the fleet did not improve from the 1991 baseline level. These estimates can then be compared with the observed number of serious injuries and fatalities.

2.4.1 Estimating serious and fatal injury counts for Australia

For Australia, counts of the number of road users killed as a result of road crashes are available from the Australian Transport Safety Bureau (2008), which provides annual counts of fatally injured occupants of motor vehicles for the period 1983-2007 with these counts disaggregated by state. The annual counts of fatally injured occupants include occupants of passenger vehicles as well as heavy vehicles. However riders of motorcycles and pillion passenger are excluded. These counts are presented in the fourth column of Table 2.

A recent report by Berry & Harrison (2008) comprehensively addressed many of the difficulties in determining counts of seriously injured road users for Australia. In doing so, the authors were able to estimate annual serious injury rates for Australia in the period 1999-2000 to 2005-2006 (see the second column of Table 2). These counts were also disaggregated by each Australian state and have been used in the current report as the best-available estimates of the number of road users seriously injured in Australia during the period for which data were available.

Berry & Harrison (2008) estimated the annual number of serious injuries for years beginning and ending at the end of June (i.e. a *financial* year). The crash data described in Section 2.1 was coded such that the *calendar* year was used to indicate when the crash occurred. In the present report, it has been assumed that serious injury trends for each financial year were indicative of serious injury trends where data were disaggregated by calendar year. This assumption is valid as there was very little variation in Berry & Harrison's (2008) serious injury counts from one year to the next (the maximum variation being a 6.5% increase from the 1999-2000 financial year to the following financial year).

Unfortunately, Berry & Harrison (2008) did not provide estimates of the number of road users seriously injured prior to 1999. For these years, serious injury counts published in the Federal Office of Road Safety's (1999) quarterly bulletins of road injury in Australia were used to estimate the number of occupants injured. These estimates are also reported in the second column of Table 2. Unfortunately, in 1999 the Federal Office of Road Safety decided to stop reporting serious injury estimates due to concerns over the consistency of serious injury reporting across jurisdictions. This meant an estimate of the number of road users seriously injured in Australia in 1998 was not available.

Berry & Harrison (2008) used hospital admission and separation data to estimate that in the financial year 2005-2006, 31,204 persons were hospitalised in Australia due to *road vehicle traffic crashes*. The authors defined a serious injury as "a person being admitted to hospital, and subsequently discharged alive either on the same day or after one or more nights stay in hospital" (p.1). Therefore, the definition of serious injury used by Berry & Harrison (2008) is consistent with the definition used in the present report.

However, Berry & Harrison (2008) defined a road vehicle traffic crash as a crash occurring on a public road involving "motor vehicles pedal cycles and other road vehicles such as trams, animals or animal-drawn vehicles" (p.1). Therefore, under their definition of serious injury, counts include injuries to motorcyclists as well as road users who would be categorised in the "other" category used by the Australian Transport Safety Bureau (2008) when reporting annual fatality counts. This meant that each of the serious injury estimates shown in Table 2 include serious injuries to all road users, including motorcyclists, bicyclists and pedestrians, while the fatality counts in the fourth column only include occupants of passenger vehicles who were killed. Fortunately, the Federal Office of Road Safety (1999) disaggregated their counts of seriously injured road users in the period 1991-1997 by road user type. The third column of Table 2 lists the number of seriously injured passenger vehicle occupants. Berry and Harrison (1997; 1998) also disaggregated their estimates of the number of seriously injured road users by road user type, but only for two years of data: 2003-2004 and 2005-2006. This meant that estimates of the number of passenger vehicle occupants seriously injured in Australia in the years 1998-2002, 2004 and 2006 were not available.

Table 2: Number of occupants of passenger vehicles who were killed or seriously injured, Australia, 1991-2006

Year of crash	Seriously injured (All traffic)*	Observed Data Seriously injured (Passenger vehicles only)†	Killed	Ratio of seriously injured to killed	Killed and seriously injured
1991	22,528	15,341	1,464	10.48	16,805
1992	21,512	14,690	1,385	10.61	16,075
1993	21,557	14,930	1,372	10.88	16,302
1994	22,133	15,498	1,310	11.83	16,808
1995	22,368	16,004	1,365	11.72	17,369
1996	21,978	15,539	1,368	11.36	16,907
1997	21,526	15,328	1,207	12.70	16,535
1998			1,209	*11.72*	15,377
1999	26,697	*14,625*	1,248	11.72	15,873
2000	26,694	*14,623*	1,302	11.23	15,925
2001	28,439	*15,579*	1,183	13.17	16,762
2002	27,526	*15,079*	1,207	12.49	16,286
2003	28,782	16,679	1,167	14.29	17,846
2004	29,849	*16,352*	1,121	14.57	17,474
2005	31,204	17,094	1,134	15.24	18,216
2006			1,093	*15.24*	17,745

* Seriously injured road users were estimated using data from the Federal Office of Road Safety (for years 1991-1997) and Berry & Harrison's (2008) report on serious injury due to land transport accidents (for 1999-2005)

† Seriously injured occupants of passenger vehicles were estimated using data from the Federal Office of Road Safety (for years 1991-1997) and Berry & Harrison's (2007; 2008) reports on serious injury due to land transport accidents (for 2003 and 2005)

Values in red italic have been estimated to reflect trends from years in which data were available

For the crash years 1999-2002 and 2004, the number of road users seriously injured were estimated by multiplying the estimated number of road users seriously injured each year (see the second column of Table 2) by an estimate of what proportion of seriously injured road users were occupants of passenger vehicles. This proportion was estimated using data from Table 3.4 on page 17 of Berry & Harrison's (2008) report, which showed that of the 31,204 road users seriously injured in 2005-2006, 6,479 were motorcyclists, 4,370 were pedal cyclists, 2,644 were pedestrians and 617 belonged to the "other or unknown" category. Excluding these groups meant that 54.8% of the 31,204 seriously injured road users were either the driver or the passenger of a motor vehicle other than a motorcycle. By multiplying the annual estimates of seriously injured road users in the second column of Table 2 by 0.548, estimates of the number of seriously injured occupants of passenger vehicles were derived. These estimates are also presented in the third column of Table 2. Serious injury counts in the third column that were estimated using this technique have been highlighted in red italic script.

It can be seen from the third column of Table 2 that estimates of the number of seriously injured occupants of passenger vehicles were still not available for crash years 1998 and 2006 due to estimates of the number of road users seriously injured not being available for these years. This prevented estimation of the aggregated number of occupants of passenger vehicles who were killed or seriously injured (column 6). To estimate these values for 1998 and 2006, the fatality counts (column 4) for these years were multiplied by the ratio of serious injuries to fatalities for years in which data were available. The fifth column of Table 2 shows the ratio of serious injuries to fatalities for occupants of passenger vehicles for years in which serious injury data were available or could be estimated. The ratio of serious injuries to fatalities for 1999 was used to estimate the number of serious injuries for 1998, while the ratio for 2005 was used to estimate the number of serious injuries in 2006. In the fifth column of Table 2 red italic script indicates ratios estimated using ratios from either the recent past or near future.

The last column of Table 2 shows the estimates of the number of occupants of passenger vehicles who were killed or seriously injured in Australia in the period 1991-2006. These estimates were derived using the method described above.

2.4.2 Estimating serious and fatal injury counts for New Zealand

Annual serious injury and fatality counts for New Zealand were derived from the Ministry of Transport's (2008) statistical summary which contained historical data on the number of road users seriously injured and the number killed for each year from 1980. Fatality counts were disaggregated by road user type so that counts could be restricted to occupants of motor vehicles (see the second-last column of Table 3), which does not include motorcyclists or pillion passengers. Such disaggregation was not available for seriously injured road users. However by estimating the proportion of road users killed each year who were occupants of motor vehicles and assuming that these proportions were also true for serious injuries, the number of seriously injured road users who were occupants of motor vehicles could be estimated. The proportion of road user killed who were occupants of motor vehicles is presented in brackets in the second-last column of Table 3. These proportions were applied to the number of seriously injured road users for each year (third column from the left) to give estimates of the number of seriously injured motor vehicle occupants in New Zealand for the period 1991-2006 (last column).

The proportion of road users receiving an injury of any severity who were occupants of motor vehicles could also have been used to estimate the number of seriously injured motor vehicle occupants for each year. However, as the proportion of all road users killed who were occupants of motor vehicles differed by the proportion of all road users injured who were occupants of motor vehicles by no more than 8.1% for any one year in the period 1991-2006, this would not have drastically changed the serious injury estimates presented in the last column of Table 3.

Table 3: Number of occupants of motor vehicles who were killed or seriously injured, New Zealand, 1991-2006

Year of crash	All Road Users		Occupants of Motor Vehicles	
	Killed	Seriously injured	Killed (% of all road users killed)	Seriously injured
1991	650	4,056	461 (70.9%)	*2,877*
1992	646	3,425	465 (72%)	*2,465*
1993	600	3,221	426 (71%)	*2,287*
1994	580	3,268	438 (75.5%)	*2,468*
1995	582	3,153	417 (71.6%)	*2,259*
1996	514	2,939	389 (75.7%)	*2,224*
1997	539	2,611	417 (77.4%)	*2,020*
1998	501	2,400	360 (71.9%)	*1,725*
1999	509	2,428	396 (77.8%)	*1,889*
2000	462	2,243	376 (81.4%)	*1,825*
2001	455	2,435	358 (78.7%)	*1,916*
2002	405	2,600	316 (78%)	*2,029*
2003	461	2,578	368 (79.8%)	*2,058*
2004	435	2,491	355 (81.6%)	*2,033*
2005	405	2,531	326 (80.5%)	*2,037*
2006	391	2,629	297 (76%)	*1,997*

Values in red italic have been estimated based on the proportion of road users killed each year who were occupants of motor vehicles

3. RESULTS

The methodology described in the previous section was applied to obtain estimates of the effect of changes in the average secondary safety of the Australian and New Zealand passenger vehicle fleets on the number of people killed or seriously injured. Results specific to New Zealand are presented first, followed by results for Australia. Section 3.3 presents the estimated effect on serious injury for Australia and New Zealand combined.

3.1. New Zealand

Sections 2.2 and 2.3 described how crash data from New Zealand were used to approximate the average crashworthiness of the New Zealand passenger vehicle fleet for each year in the period 1991-2006.

Figure 3 shows the average crashworthiness of the New Zealand fleet for each year in the period 1991-2006. It can be seen from Figure 3 that in 1991, the average crashworthiness of the New Zealand fleet was estimated to be about 7.5% and a year later it rose to 8.1%. In section 3.2 of the current report, it is shown that the secondary safety index of the Australian passenger fleet descends with each passing year (See Figure 6). The average crashworthiness of the New Zealand fleet did not just increase in 1992, but also in 1999 and 2003. However, in general, the secondary safety index for New Zealand has decreased over the period from 1991 to 2006.

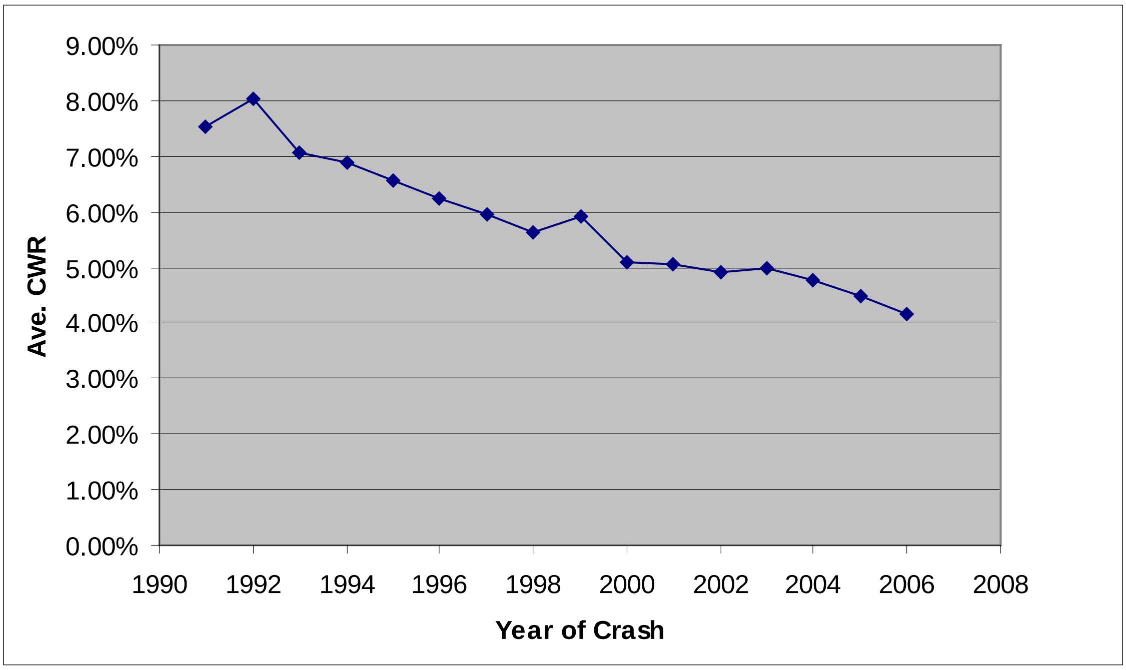

Figure 3: Secondary Safety Index (average fleet crashworthiness rating) for the New Zealand passenger vehicle fleet, 1991-2006 (estimated using NZ crash data)

The reason New Zealand's secondary safety index increased in some years could be due to New Zealand's used car import program. As explained by Keall & Newstead (2008), the New Zealand fleet is different to Australia's fleet in that a relatively high proportion of vehicles in New Zealand are used cars imported into the fleet from overseas, mainly Japan.

This means that New Zealand's secondary safety index for a year is dependent on the volume and type of used vehicles imported into the fleet during the year and during preceding years. If a relatively high number of used vehicles of relatively poor crashworthiness are imported into the fleet in a year, this may cause a rise in the average crashworthiness of the fleet for that year. Furthermore, as the present report has used crash data to approximate the passenger vehicle fleet, this peak in the average crashworthiness may not be observed until several years after the vehicles were imported. Keall & Newstead (2008) demonstrated that the average crashworthiness of New Zealand's passenger vehicle fleet also increased for some years when the fleet was approximated using crash data.

Table 4: Estimation of the number of occupants of motor vehicles who were involved in police-reported crashes using the observed SSI and the number of seriously injured or killed occupants, New Zealand, 1991-2006

Year of crash	Actual SSI	Occupants of Motor Vehicles: Killed or Seriously injured	Occupants of Motor Vehicles: Involved in police-reported crashes
1991	7.52%	3,338	44,362
1992	8.05%	2,930	36,409
1993	7.08%	2,713	38,345
1994	6.88%	2,906	42,223
1995	6.57%	2,676	40,704
1996	6.25%	2,613	41,801
1997	5.94%	2,437	41,016
1998	5.63%	2,085	37,023
1999	5.93%	2,285	38,541
2000	5.11%	2,201	43,105
2001	5.05%	2,274	45,034
2002	4.90%	2,345	47,822
2003	4.98%	2,426	48,681
2004	4.76%	2,388	50,207
2005	4.49%	2,363	52,578
2006	4.18%	2,294	54,930

As explained in section 2.4, the New Zealand Ministry of Transport's (2008) statistical summary was used to estimate the number of occupants who were killed or seriously injured. These estimates can be divided by each year's secondary safety index to give estimates of the number of occupants involved in police-reported crashes in New Zealand, which are shown in the right-most column of Table 4. Figure 4 shows a graphical representation of the estimated number of seriously injured or killed occupants and the number of occupants involved in police-reported crashes in New Zealand. It can be seen that the estimated number of occupants involved in police-reported crashes increased from the late 1990s up until 2006. However the number of occupants killed or seriously injured did not increase at a similar rate. For example, the estimated number of people involved in police-reported crashes in 2006 was 42.5% greater than the number involved in police-reported crashes in 1999, while the number of people killed or seriously injured in 2006 was only 0.4% greater. Figure 3 showed that from 2003 onwards, the secondary safety index of the New Zealand fleet steadily improved. This would partly explain why the number of occupants who were seriously injured or killed remained relatively stable during this period while the number involved in police-reported crashes increased steadily.

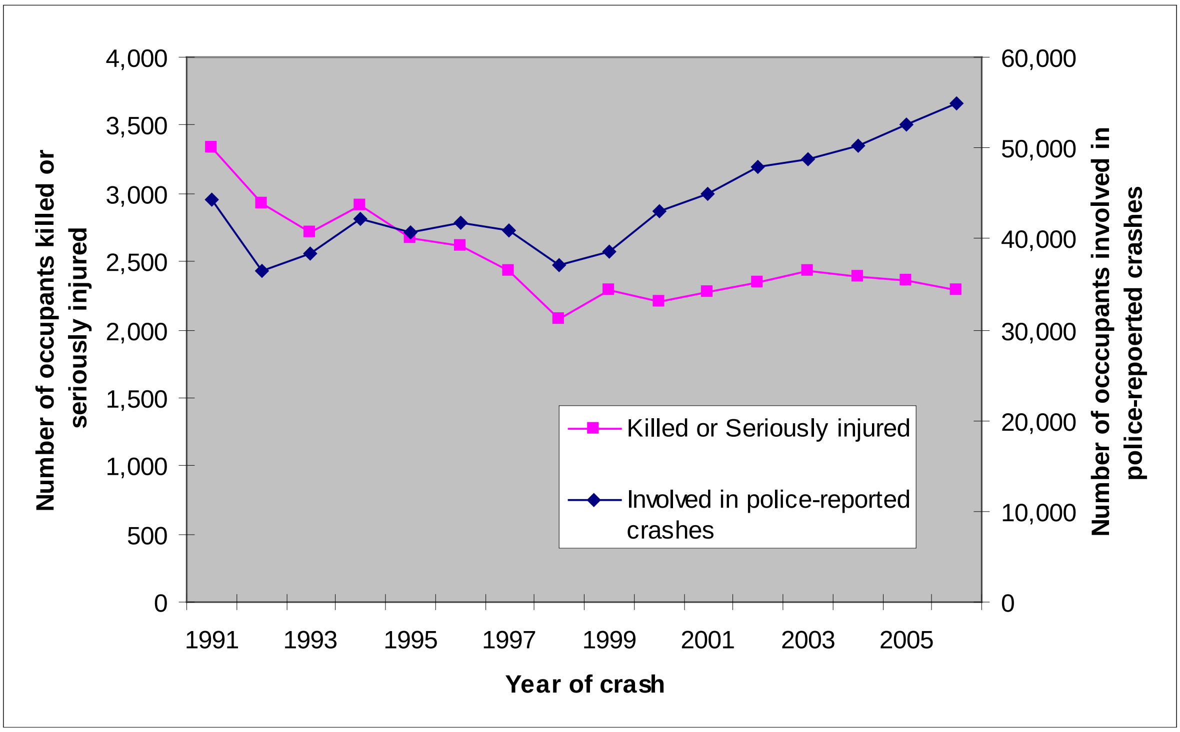

Figure 4: Estimation of the number of occupants of motor vehicles involved in police-reported crashes and the number seriously injured or killed in police-reported crashes, New Zealand, 1991-2006

Table 5 shows the number of occupants killed or seriously injured in New Zealand, as reported by the Ministry of Transport (2008) compared to the number if the secondary safety index remained at the 1991 level for the period 1991-2006. The right-most column of Table 5 shows that if the secondary safety of the New Zealand fleet had not improved since 1991, more than 12,000 additional occupants would have been seriously injured or killed in the period 1991-2006. This is a 31.3% increase than the number of seriously injured or killed occupants actually observed.

The secondary safety index used to derive the estimates presented in Table 5 was defined using a metric of secondary safety that measured the risk of a driver being killed or hospitalised when they were involved in police-reported crash. If it is assumed that the relative changes in the secondary safety index from year to year also reflect relative changes in the risk of an occupant being killed when involved in a police-reported crash, this secondary safety index can also be used to estimate how many more fatalities could be expected in New Zealand for each year in the period 1991-2006 if the secondary safety of the fleet had not improved since 1991. This can be done using equation 5 of section 2.4 but letting S_{jk} be equal to the observed number of occupants killed in New Zealand in year k (from the fourth column of Table 3) instead of the observed number of occupants seriously injured or killed.

Table 5: Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (8.48%), New Zealand, 1991-2006

Year of crash	Killed or seriously injured occupants of motor vehicles		Difference	Cumulative
	Actual SSI	Baseline SSI (7.52%)		
1991	3,338	3,338	0	0
1992	2,930	2,739	-191	-191
1993	2,713	2,885	172	-19
1994	2,906	3,177	271	252
1995	2,676	3,062	386	638
1996	2,613	3,145	532	1,170
1997	2,437	3,086	649	1,819
1998	2,085	2,785	701	2,520
1999	2,285	2,900	615	3,134
2000	2,201	3,243	1,042	4,176
2001	2,274	3,388	1,114	5,290
2002	2,345	3,598	1,253	6,544
2003	2,426	3,663	1,237	7,780
2004	2,388	3,777	1,390	9,170
2005	2,363	3,956	1,593	10,762
2006	2,294	4,133	1,839	12,601

In Table 6, the assumption and the method described in the previous paragraph were applied to give the estimates of the annual number of occupants killed in New Zealand if the secondary safety index remained at the 1991 level for the period 1991-2006 compared to the observed number of occupants killed (from Ministry of Transport, 2008). The reader should be aware that the validity of this additional assumption has not been tested. Presently there are an insufficient number of cases to assign reliable secondary safety metrics that specifically measure the risk of death. This is why the crashworthiness metric developed by Cameron, Finch & Le (1994) measured secondary safety in terms of the risk of serious injury or death. The prospect of developing an index specifically related to death is examined in the discussion section of this report.

It can be seen from Table 6 that if the secondary safety index of the New Zealand passenger vehicle fleet was the same in 2006 as it was in 1991, it is estimated that an additional 238 fatalities would have occurred. This is an 80.2% increase on the number of fatalities actually observed (297). It is also estimated that nearly 1,900 additional fatalities would have occurred over the period 1991-2006 if the secondary safety of the New Zealand fleet had not improved since 1991, which is 30.7% higher than the number of fatalities actually observed (6,165).

Table 6: Estimation of the number of occupants of motor vehicles who would have been killed if the secondary safety of the fleet had not improved from the baseline 1991 level (8.48%), New Zealand, 1991-2006

Year of crash	Killed occupants of motor vehicles		Difference	Cumulative
	Actual SSI	Baseline SSI (7.52%)		
1991	461	461	0	0
1992	465	435	-30	-30
1993	426	453	27	-3
1994	438	479	41	38
1995	417	477	60	98
1996	389	468	79	177
1997	417	528	111	288
1998	360	481	121	409
1999	396	503	107	515
2000	376	554	178	693
2001	358	533	175	869
2002	316	485	169	1,038
2003	368	556	188	1,225
2004	355	562	207	1,432
2005	326	546	220	1,652
2006	297	535	238	1,890

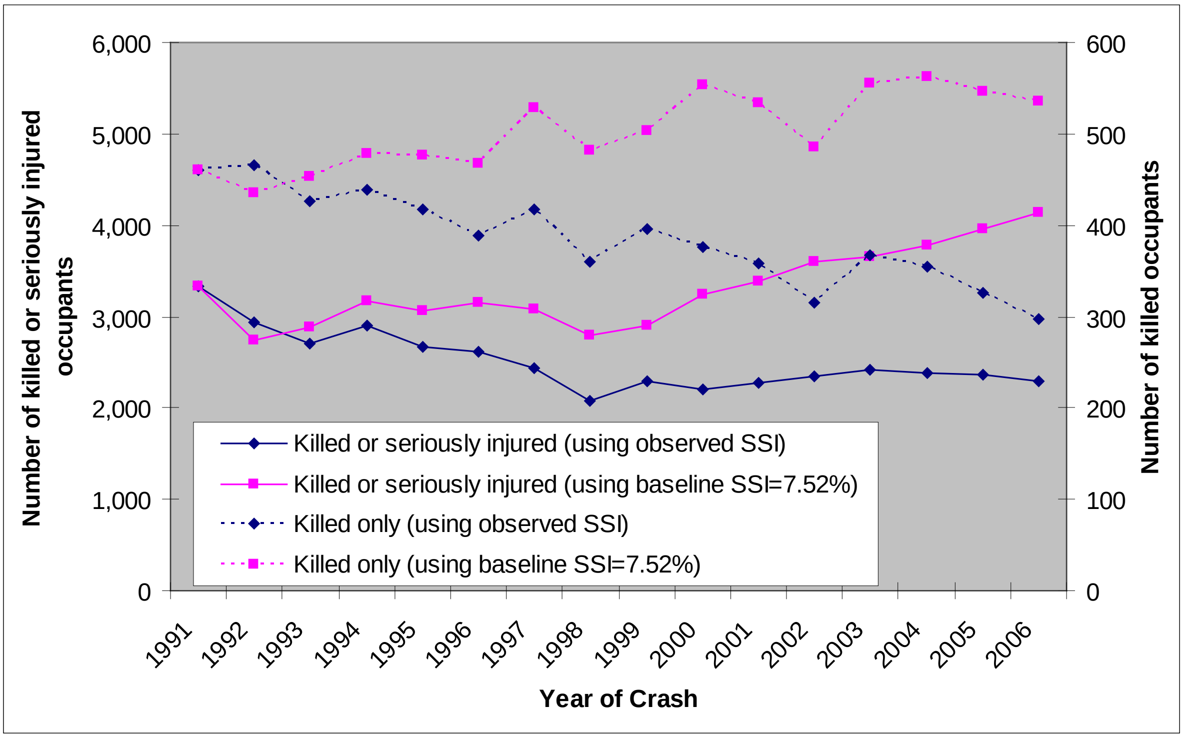

Figure 5: Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (7.52%), New Zealand, 1991-2006

Figure 5 shows a graphical representation of how the trends of the number of occupants seriously injured or killed in New Zealand would differ to those observed if there were no improvement to the secondary safety of the fleet in the period 1991-2006. Blue data points represent observed serious injury and fatality counts while pink data points represent annual estimates that would have been expected if the secondary safety of the fleet had not improved. Dotted lines represent trends for the number of occupants killed, while solid lines represent the trends for the number of occupants killed or seriously injured. Values on the left vertical axis correspond to estimates of occupants killed or seriously injured, while values on the right vertical axis correspond to estimates of occupants killed. For both measures of road trauma the observed annual counts and the annual counts estimated assuming the baseline secondary safety index become more disparate with each increasing crash year. This is because, in general, the secondary safety index of the New Zealand passenger vehicle fleet improved over time (see Figure 3).

3.2. Australia

This section describes how the effect of improvements to the secondary safety of the Australian fleet on the number of seriously injured or killed occupants was examined. This effect was examined by first estimating the average crashworthiness of the Australian passenger vehicle fleet for each year in the period 1991-2006. As was the case in the previous section where a secondary safety index for New Zealand was defined, the average crashworthiness of the Australian fleet was defined using crash data. Figure 6 graphs the secondary safety of the Australian passenger fleet and shows that in 1991 the average crashworthiness of Australian passenger vehicles was 4.47%. This meant that in 1991, when an occupant of a passenger vehicle was involved in a police-reported crash in Australia, the risk of them being seriously injured or killed was estimated to be 4.47%. This risk of serious injury or death decreased steadily over the next fifteen years so that by 2006 there was estimated to be a 3.31% chance of serious injury or death when an occupant of a passenger vehicle was involved in a police-reported crash.

The crash data used to produce the secondary safety index for Australia was provided by five Australian states: New South Wales, Queensland, South Australia, Victoria & Western Australia. The driving conditions and populations of the different states of Australia differ from each other, so it is possible that there are differences between the states in the average crashworthiness of their passenger vehicle fleets. However Figure 7 shows that the secondary safety index in the period 1991-2006 did not vary greatly when disaggregated across the five Australian jurisdictions.

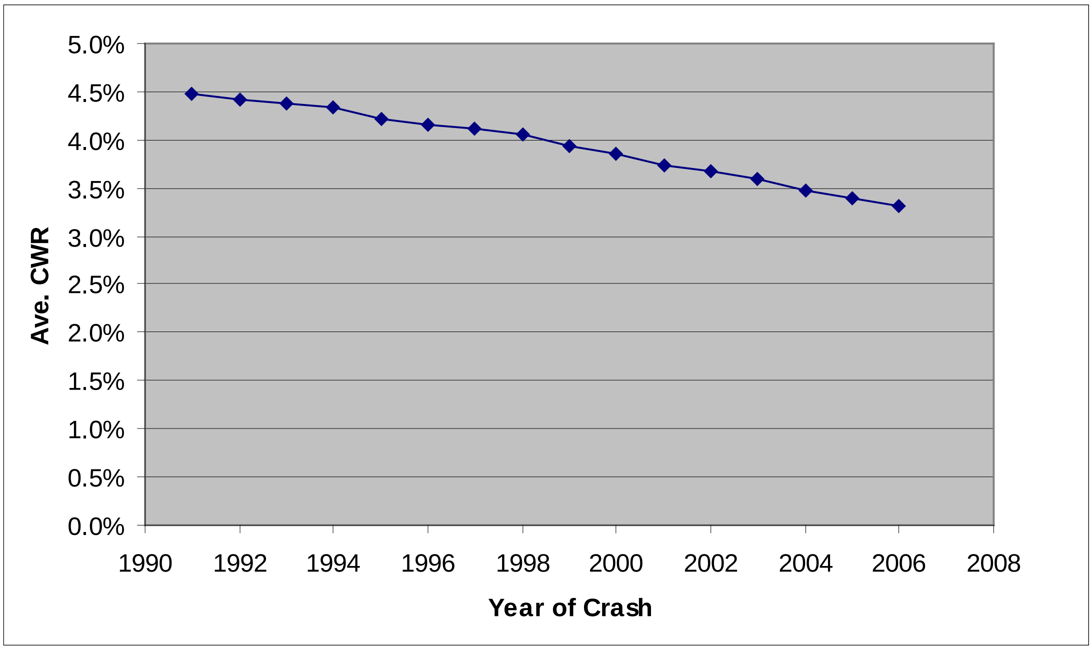

Figure 6: Secondary Safety Index (average fleet crashworthiness rating) for the Australian passenger vehicle fleet, 1991-2006 (estimated from crash data from five jurisdictions)

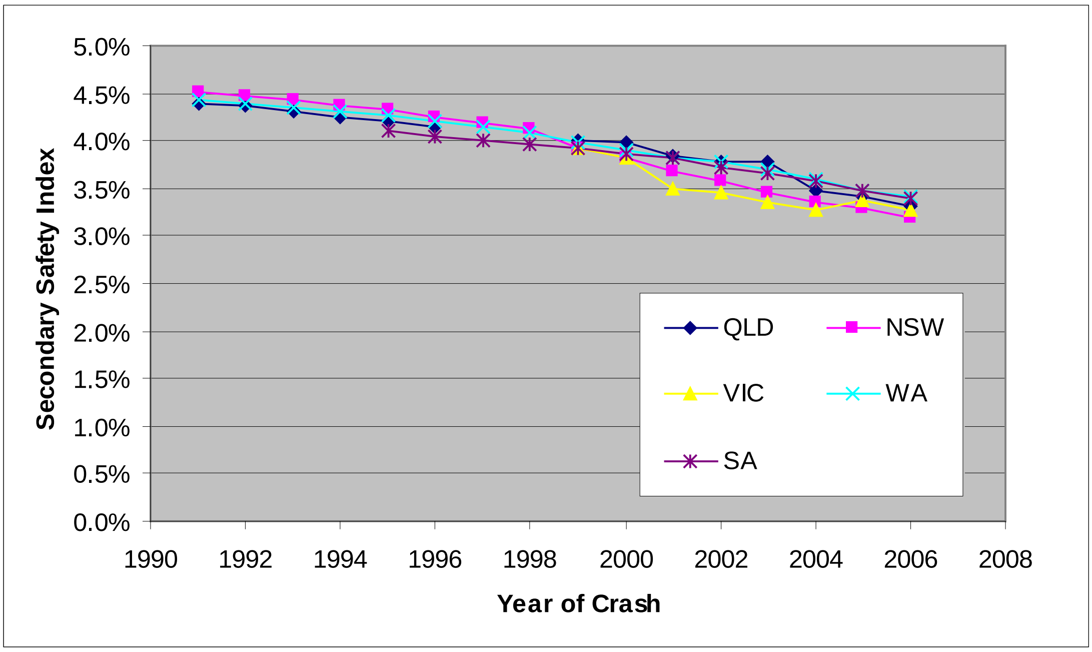

Figure 7: Secondary Safety Index (average fleet crashworthiness rating) for five Australian jurisdictions, 1991-2006

As described in Section 2.4, the secondary safety index of the Australian fleet and the observed number of occupants seriously injured or killed could be used to estimate the annual number of occupants involved in police-reported crashes during 1991-2006. Table 7 shows the secondary safety index estimates for Australia along with the observed number of occupants killed or seriously injured. These were both used to derive the estimates of the number of occupants involved in police-reported crashes each year, which are shown in the right-most column. Figure 8 graphically compares the estimates of the number of occupants killed or seriously injured and the number of occupants involved in police-reported crashes. As the trend of the number of occupants involved in police-reported crashes was derived using the observed trend of the number of occupants killed or seriously injured, the relative changes from year-to-year for the two trends are similar.

Table 7: Estimation of the number of occupants of motor vehicles who were involved in police-reported crashes using the observed Serious Safety Index (SSI) and the number of seriously injured or killed occupants, Australia, 1991-2006

Year of crash	Actual SSI	Occupants of Motor Vehicles	
		Killed or Seriously injured	Involved in police-reported crashes
1991	4.47%	16,805	376,037
1992	4.43%	16,075	363,124
1993	4.38%	16,302	372,118
1994	4.33%	16,808	388,127
1995	4.22%	17,369	411,246
1996	4.16%	16,907	406,283
1997	4.11%	16,535	402,014
1998	4.06%	15,377	378,650
1999	3.94%	15,873	402,466
2000	3.86%	15,925	412,058
2001	3.74%	16,762	447,785
2002	3.67%	16,286	443,950
2003	3.58%	17,846	497,827
2004	3.47%	17,474	504,109
2005	3.40%	18,216	536,392
2006	3.31%	17,745	535,710

It can also be seen from Figure 8 that from 1998 the number of occupants involved in police-reported crashes has increased steadily. The number of occupants seriously injured or killed has also increased, but not by the same magnitude. For example, from 1998 to 2006, the number of occupants killed or seriously injured in Australia increased by 13.3%, while the number of occupants involved in police-reported crashes increased by 29.3%. The reason that the number of occupants killed or seriously injured increased to a lesser degree than for the number of occupants killed or seriously injured was that the serious safety index for the Australian passenger vehicle fleet improved during the period (see Figure 6).

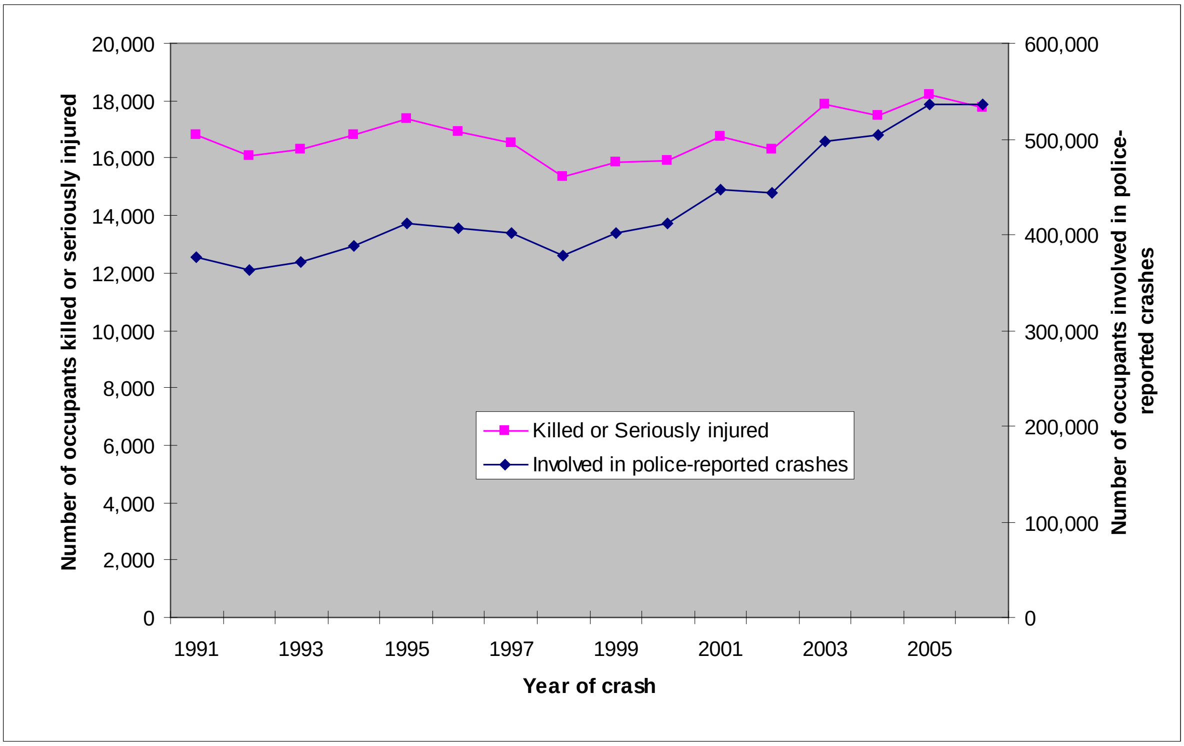

Figure 8: Estimation of the number of occupants of motor vehicles involved in police-reported crashes and the number seriously injured or killed in police-reported crashes, Australia, 1991-2006

Table 8 shows the estimated observed number of occupants killed or seriously injured in Australia compared to the number if the secondary safety index remained at the 1991 level for the period 1991-2006. The secondary safety index was estimated to be 4.47% in 1991 (see Table 7). As explained in Section 2.4, for each year in the period 1991-2006, the number of occupants killed or seriously injured if it was assumed that the secondary safety of the fleet remained at the baseline value could be calculated by multiplying the observed number of occupants killed or seriously injured by the ratio of the baseline serious safety index to the observed secondary safety index (see equation 6 of section 2.4).

The fourth column of Table 8 shows the difference between the annual estimates based on the baseline secondary safety index and the observed secondary safety index. It can be seen that as the observed secondary safety index improves with each passing year, there is an increase in the difference between the observed number of occupants killed or seriously injured and the number estimated if there were no improvements to secondary safety. The right-most column of Table 8 shows it is estimated that, over the period 1991-2006, an additional 39,000 cases of occupants being seriously injured or killed would be expected if the secondary safety of the fleet had not improved since 1991. Therefore the number of serious injuries and fatalities observed in the period 1991-2006 would have increased by 14.6% if the secondary safety of the fleet had not improved since 1991.

Table 8: Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), Australia, 1991-2006

Year of crash	Killed or seriously injured occupants of motor vehicles		Difference	Cumulative
	Actual SSI	Baseline SSI (4.47%)		
1991	16,805	16,805	0	0
1992	16,075	16,228	153	153
1993	16,302	16,630	328	481
1994	16,808	17,345	537	1,018
1995	17,369	18,379	1,010	2,028
1996	16,907	18,157	1,250	3,277
1997	16,535	17,966	1,431	4,708
1998	15,377	16,922	1,545	6,253
1999	15,873	17,986	2,113	8,366
2000	15,925	18,415	2,489	10,856
2001	16,762	20,011	3,249	14,105
2002	16,286	19,840	3,554	17,659
2003	17,846	22,248	4,402	22,060
2004	17,474	22,529	5,055	27,115
2005	18,216	23,971	5,755	32,870
2006	17,745	23,941	6,196	39,066

If it is assumed that the relative changes in the secondary safety index from year to year for the Australian vehicle fleet also reflect relative changes in the risk of death given an occupant is involved in a police-reported crash, then the ratio of the baseline secondary safety index to the observed secondary safety index can be used to estimate the number of fatalities that would be expected if the secondary safety of the fleet had not improved since 1991. As explained in section 3.1, this can be done simply by substituting into equation 6 the observed number of occupant fatalities for each Australian jurisdiction for each year.

As previously mentioned, it has not yet been established whether relative changes in the secondary safety index accurately reflect relative changes in the risk of death from year to year. The reader should be aware that this assumption has not been tested when interpreting Table 9 which shows estimates of the annual number of occupants killed in Australia if the secondary safety index remained at the 1991 level compared to the observed number of occupants killed. As previously mentioned, the prospect of developing an index specifically related to occupant death is examined in the discussion section of this report.

It can be seen from Table 9 that if the secondary safety index of the Australian passenger vehicle fleet was the same in 2006 as it was in 1991, it is estimated that 382 more occupants of passenger vehicles would have been killed in 2006. This is a 34.9% increase than the number of fatalities actually observed (1,093). It was shown in Section 3.1 that if the secondary safety of the New Zealand fleet had not improved since 1991, the number of occupants killed would have been expected to be 80.2% higher than that observed in 2006.

This demonstrates that the amount that the extent of the improvement in secondary safety of New Zealand fleet over the period 1991-2006 was greater than that for Australia. For example, the secondary safety index for New Zealand declined from 7.52% in 1991 to 4.18% in 2006, which is a reduction of 44.5%. For Australia, the secondary safety index dropped from 4.47% in 1991 to 3.31% in 2006, which is a reduction of 25.9%.

Table 9: Estimation of the number of occupants of motor vehicles who would have been killed if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), Australia, 1991-2006

Year of crash	Killed occupants of motor vehicles		Difference	Cumulative
	Actual SSI	Baseline SSI (4.47%)		
1991	1,464	1,464	0	0
1992	1,385	1,398	13	13
1993	1,372	1,400	28	41
1994	1,310	1,352	42	83
1995	1,365	1,444	79	162
1996	1,368	1,469	101	263
1997	1,207	1,311	104	368
1998	1,209	1,330	121	489
1999	1,248	1,414	166	655
2000	1,302	1,506	204	859
2001	1,183	1,412	229	1,088
2002	1,207	1,470	263	1,351
2003	1,167	1,455	288	1,639
2004	1,122	1,447	325	1,964
2005	1,122	1,476	354	2,318
2006	1,093	1,475	382	2,700

It is also estimated that 2,700 additional fatalities would have occurred over the period 1991-2006 if the secondary safety of the Australian fleet had not improved since 1991, which is 13.4% higher than the number of fatalities actually observed (20,124). By comparison, for New Zealand, it was estimated that the number of occupants killed would have been 30.7% higher if the secondary safety of the fleet had not improved since 1991.

Figure 9 shows a graphical representation of the difference between estimates of the number of occupants killed or seriously injured derived using the baseline secondary safety index compared to when the observed secondary safety index was used. Annual counts based on the observed serious safety index of each year (blue markers) and baseline baseline serious safety index (pink markers) have been given for fatally injured occupants only (dotted lines) as well as for the aggregated counts of killed occupants and seriously injured occupants (solid lines). Figure 9 relates only to Australia but can be compared with Figure 5 in the previous section which shows analogous trends for New Zealand. As was the case for New Zealand, the observed road trauma trends become more disparate from the trends based on the baseline secondary safety index with each passing crash year. As was the case for New Zealand, this is because the secondary safety index of the Australian passenger vehicle fleet improved over time (see Figure 6).

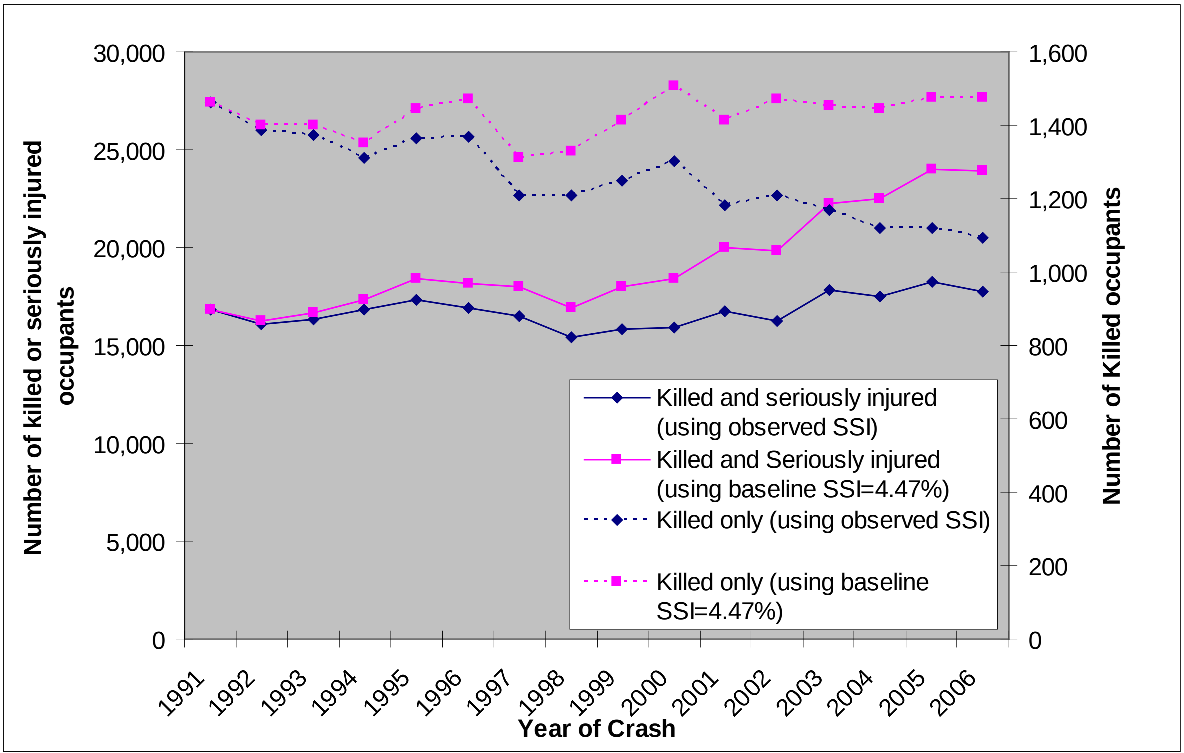

Figure 9: Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), Australia, 1991-2006

3.3. Australian States

The following sections show the estimated number of occupants killed or seriously injured for each of the five Australian jurisdictions if the secondary safety of those jurisdictions had not improved since 1991. To do this for each of the five jurisdictions, it was necessary to obtain the observed number of occupants killed or seriously injured in each jurisdiction for each year in the period 1991-2006 and also estimate a separate serious safety index for each jurisdiction.

Figure 7 in Section 3.2 demonstrated that the serious safety index for Australia as a whole was very similar to the serious safety indices for each of the five Australian jurisdictions for which police-reported crash data were available. Therefore, it was decided that, in the following sections, the serious safety index for each Australian jurisdiction would be assumed to be equal to that previously estimated for all Australian jurisdictions combined. That is, it was assumed that the secondary safety index of each of the five Australian jurisdictions was approximately equal to 4.47% in 1991, gradually improving to 3.31% by 2006. This enabled a secondary safety index for each jurisdiction to be estimated for each year in the period 1991-2006, even though some jurisdictions (such as Queensland, South Australia and Victoria) could not provide suitable crash data for some years in period 1991-2006.

For each jurisdiction, the annual number of occupants of passenger vehicles who were killed was estimated using the Australian Transport Safety Bureau's (2008) Statistical Summary of

Road Deaths for 2007 which contained historical fatality data by the state in which the crash occurred.

Obtaining estimates of the number of occupants seriously injured for each jurisdiction was a much more challenging task. Firstly, as previously mentioned, the types of injuries that will be coded as serious will differ for different states. This is because different states have different methods of collecting data on serious injuries and even when definitions of serious injuries are consistent, differences in the way injuries are dealt with by each state's health service providers means that the same injury may be classified as serious by one jurisdiction but not another. Another problem is that while data on serious injuries aggregated across Australia are available from publications such as Berry & Harrison (2007; 2008), data disaggregated by State are not commonly available. This is partly because some states such as New South Wales do not report annual numbers of seriously injured road users because they are aware of inconsistencies in the way serious injury data are collected.

For each jurisdiction, annual serious injury counts for the years 2003 and 2005 were taken from reports by Berry & Harrison (2007; 2008), while for the years 1991-1996, counts of the number of seriously injured occupants of passenger vehicles were taken from the 1996 statistical summary of road injury in Australia, which was published by the Federal Office of Road Safety (1998).

For the period 1997-2002, serious injury counts disaggregated by jurisdiction were not published by the Federal Office of Road Safety nor its successor, the Australian Transport Safety Bureau. This could be because of New South Wales' decision not to differentiate between injured road users and seriously injured road users. In order to overcome this deficiency, a method had to be devised to estimate the number of seriously injured occupants of passenger vehicles in the five Australian jurisdictions. For each jurisdiction except Victoria, the annual number of occupants killed in each state in the period 1997-2002 was multiplied by the national ratio of seriously injured occupants to killed occupants for each crash year. These ratios were presented in the fifth column of Table 2 in Section 2.4 of this report. This method was not used to estimate the number of serious injuries in Victoria as it was observed using data from Berry & Harrison (2007; 2008) and the Federal Office of Road Safety (1998) that the ratio of seriously injured occupants of passenger vehicles to killed occupants of passenger vehicles for each year was consistently higher for Victoria than for other states. For each year in which data were available, the annual serious to fatal ratios were fairly consistent across the remaining five states. The most-likely reason the annual serious injury to fatality ratios for Victoria were higher than those of other states is that in the Victorian police-reported database, a road user is classed as seriously injured if they are transported to hospital by ambulance, while in others states a road user is classified as being seriously injured if they are admitted to hospital. Due to the disparity in ratios for Victoria compared with other states, Victorian police-reported crash data were used to provide accurate estimates of serious injury for Victoria for the period 1997-2002 and the years 2004 and 2006.

Much has been written in recent years about the difficulties in estimating the number of seriously injured road users in each Australian State (for example Giles, 2001; Chapman & Rosman, 2008). The present report has not sought to accurately estimate the number of seriously injured occupants of passenger vehicles for each Australian state. Other reports such as Chapman & Rosman (2008) have already commented in detail on the difficulty of such a task. Rather, the present report has generated a profile of serious injury counts that is broadly representative of how counts of seriously injured road users are disaggregated over time and across jurisdictions. This profile can be used as a way of comparing the affect of improved secondary safety between jurisdictions.

The following sections present how improved secondary safety has affected counts of fatally injured occupants for each of the five Australian jurisdictions for which police-reported crash data were available. Each section presents estimates of the effect of improved secondary safety for a specific jurisdiction. However, in order to compare the effect of improved secondary safety for different jurisdictions, Figures 9 and 10 summarise the results from the following sections so that savings for each jurisdiction can be compared on the same set of axes. Figure 10 shows estimates of how many additional occupants would have been killed or seriously injured had there been no improvements in secondary safety since 1991 disaggregated across each of the five jurisdictions, while Figure 11 shows the estimated savings in terms of occupant fatalities.

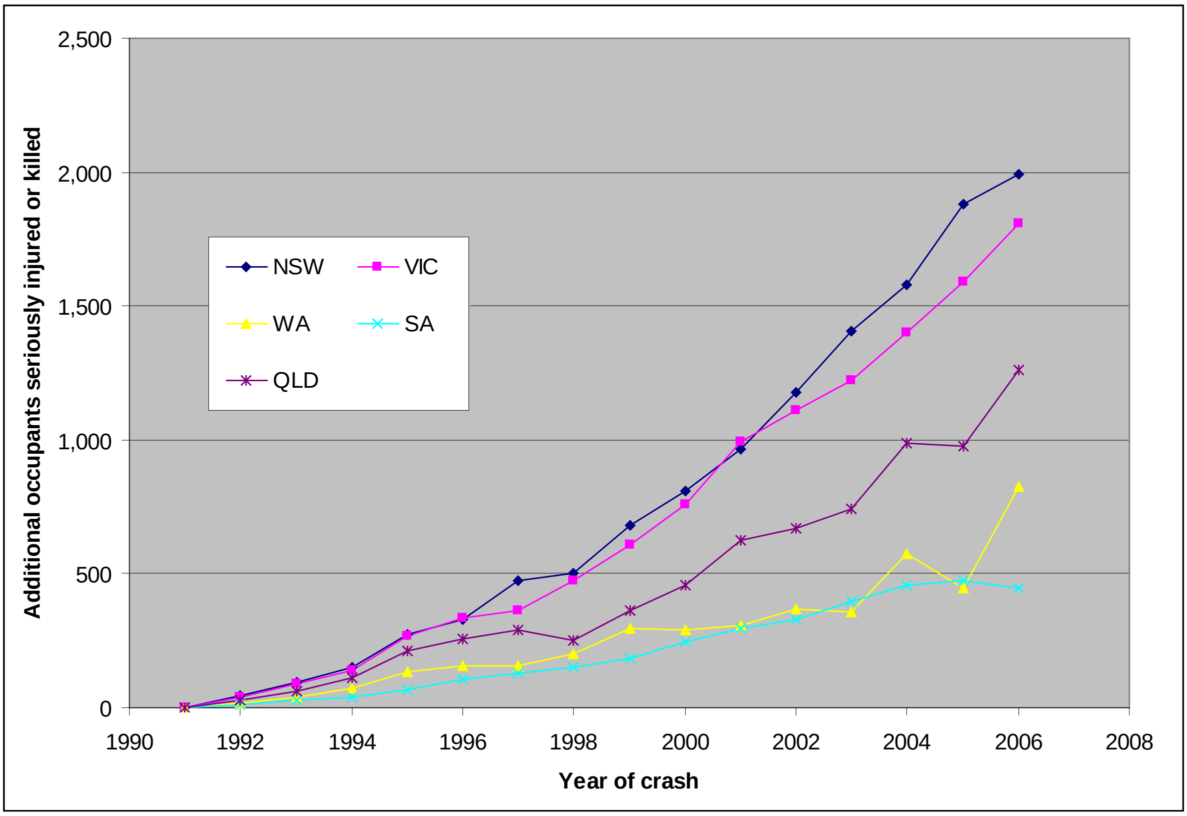

Figure 10: Estimation of the additional annual number of occupants who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%) by Australian jurisdiction, 1991-2006

It can be seen from both of these figures that the states with the largest fleets have experienced the greatest savings due to improvements in secondary safety. For example, Australian Bureau of Statistics (2008) demographic data reveal that the most-populated state is New South Wales, followed by Victoria, Queensland and South Australia. It is not unexpected that the level of savings exhibited for each jurisdiction is strongly related to the size of the population as this report assumed that the secondary safety index did not vary between Australian states. This means that differences between states in the estimated effect of improvements to secondary safety will be determined by the observed annual number of seriously injured or killed occupants in each state.

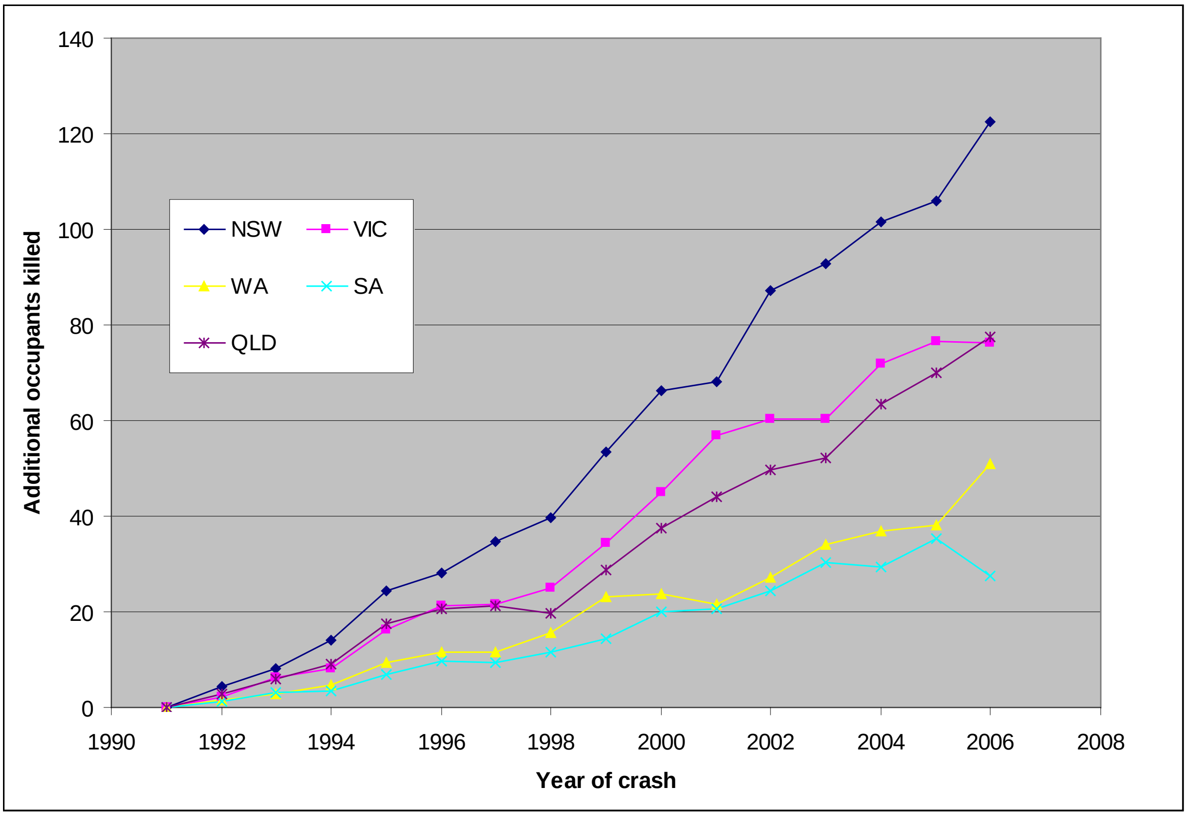

Figure 11: Estimation of the additional annual number of occupant fatalities if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%) by Australian jurisdiction, 1991-2006

Both Figures 9 and 10 show that, in general, with each passing year, the number of lives saved or serious injuries prevented increases for each jurisdiction. This occurs because with each passing year, the secondary safety of the Australian passenger vehicle fleet improves (see Figure 6 of Section 3.2), so the disparity between the observed secondary safety index and the baseline secondary safety index increases with each passing year. Apart from some minor aberrations, South Australia is the only state for which the benefits of improved secondary safety of the fleet do not appear to increase with each passing year. It can be seen from Figure 10 that, unlike trends exhibited by other states, for South Australia the estimated additional number of occupants who would have been seriously injured or killed each year if secondary safety had not improved levels off from 2004 onwards. This trend could be a result of South Australia's population increasing less rapidly than that observed for the other states. This will be explored further in Section 3.3.3. Other localised aberrations, such as the number of serious injuries prevented dropping in 2005 for Western Australia, occurred as a result of the previously-explained method for imputing the number of seriously injured road users within jurisdictions when such observations were not available for some crash years. For example in the case of Western Australia in 2005, the observed number of serious injuries was not available so the number was estimated by multiplying the observed number of fatalities by the serious injury to fatality ratio observed for all five Australian jurisdictions in 2005, which was less than the ratio specific to Western Australia in the years preceding and following 2005.

As previously mentioned, each jurisdiction has accurate records of road fatalities by road user type and year of death and these data are reported in the Australian Transport Safety Bureau's (2008) summary of road deaths. As in previous sections it has been assumed that relative changes in the secondary safety index affect the number of occupants killed in the same way as they affect the number of occupants seriously injured. As previously mentioned, the validity of this assumption has yet to be tested.

Sections 3.3.1 to 3.3.5 below present the jurisdiction-specific estimates used to derive the trends reported in Figures 9 and 10.

3.3.1. New South Wales

The second column of Table 10 shows the observed number of seriously injured or killed occupants of passenger vehicles in New South Wales for the period 1991-2006. As previously explained, annual counts of occupants who were seriously injured or killed in the period 1991-2006 were obtained from the Federal Office of Road Safety (1998), while estimates for 2003 and 2005 were obtained from Berry & Harrison's 2007 and 2008 reports respectively. All other observed counts were estimated using the ratio of seriously injured occupants to killed occupants that were observed for Australia (see Table 2 of Section 2.4).

Table 10: Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), New South Wales, 1991-2006

Year of crash	Killed or seriously injured occupants of motor vehicles		Difference	Cumulative
	Actual SSI	Baseline SSI (4.47%)		
1991	5,039	5,039	0	0
1992	4,834	4,880	46	46
1993	4,800	4,897	97	143
1994	4,654	4,803	149	291
1995	4,689	4,962	273	564
1996	4,454	4,783	329	893
1997	5,480	5,954	474	1,367
1998	5,024	5,529	505	1,872
1999	5,113	5,794	681	2,553
2000	5,186	5,997	811	3,363
2001	4,988	5,954	967	4,330
2002	5,384	6,559	1,175	5,505
2003	5,698	7,103	1,405	6,910
2004	5,466	7,048	1,581	8,492
2005	5,953	7,834	1,881	10,373
2006	5,699	7,688	1,990	12,362

The third column of Table 10 shows how the number of occupants seriously injured or killed in New South Wales would have increased if the secondary safety of the New South Wales passenger vehicle fleet had not improved since 1991. It can be seen that had the secondary safety index remained at 1991 levels, an estimated 46 additional occupants would have been killed or seriously injured in 1992. However in 2006, it was estimated that nearly two thousand additional occupants would have been seriously injured or killed had the secondary safety of the New South Wales fleet not improved. The fifth column of Table 10 shows that by 2006, it was estimated that more than 12,000 additional occupants would have been seriously injured or killed had the secondary safety of the New South Wales fleet not improved since 1991.

The third column of Table 11 shows the estimated number of occupants who would have been killed if the secondary safety of the New South Wales passenger vehicle fleet had not improved since 1991 compared to the actual number of fatalities in the period 1991-2006 (see the second column). It can be seen that in 1992, it was estimated that improvements to the secondary safety of the New South Wales fleet resulted in four fewer fatalities. However by 2006, it was estimated that an additional 123 lives would have been lost in that year if the secondary safety of the fleet had remained at 1991 levels. Over the period 1991-2006, it was estimated that about 850 additional occupants would have died had the secondary safety of the New South Wales fleet not improved since 1991.

Table 11: Estimation of the number of occupants of motor vehicles who would have been killed if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), New South Wales, 1991-2006

Year of crash	Killed occupants of motor vehicles		Difference	Cumulative
	Actual SSI	Baseline SSI (4.47%)		
1991	476	476	0	0
1992	463	467	4	4
1993	409	417	8	13
1994	438	452	14	27
1995	420	444	24	51
1996	380	408	28	79
1997	400	435	35	114
1998	395	435	40	153
1999	402	456	54	207
2000	424	490	66	273
2001	352	420	68	341
2002	399	486	87	429
2003	376	469	93	521
2004	351	453	102	623
2005	335	441	106	729
2006	351	474	123	851

A graphical illustration of the effect of improvements to the secondary safety of the New South Wales passenger vehicle fleet on the number of occupants seriously injured or killed has been presented in Figure 12. Solid lines represent estimates of the number of occupants killed or seriously injured, while dotted lines represent estimates of occupants who were killed. The right vertical axis corresponds to estimates relating to fatalities only, while the left axis corresponds to estimates for fatalities and seriously injured occupants. Pink markers represent estimates of the actual number of casualties while blue markers represent the number estimated if secondary safety improvements had not occurred.

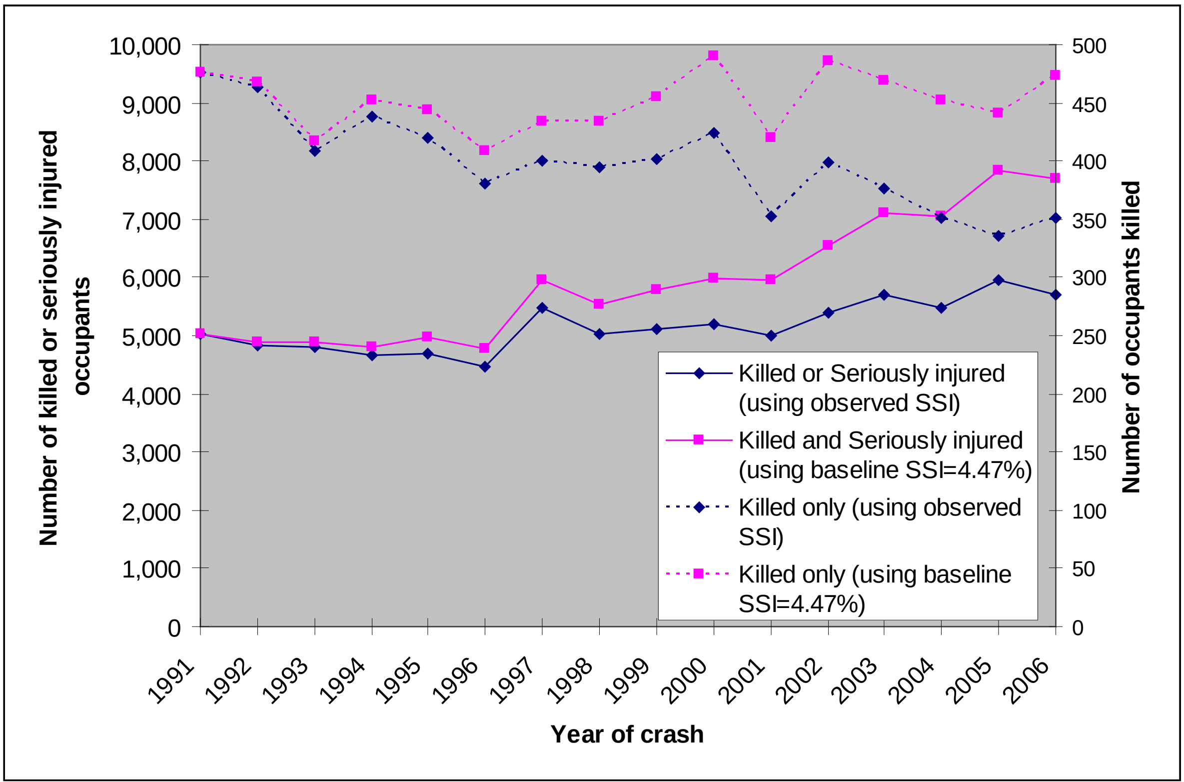

Figure 12: Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), New South Wales, 1991-2006

3.3.2. Queensland

In this section, the observed number of seriously injured or killed occupants of passenger vehicles in Queensland are used to estimate the number of occupants who would have been injured or killed if the secondary safety of the Queensland fleet had not improved since 1991. For each year in the period 1991-2006, the number of occupants killed in Queensland was provided by the Australian Transport Safety Bureau's (2008) statistical summary of road deaths, while for the period 1991-1997, estimates of the number of occupants seriously injured were taken from the Federal Office of Road Safety's (1998) statistical report on road injury in Australia. As was the case for New South Wales, estimates for 2003 and 2005 were obtained from Berry & Harrison's 2007 and 2008 reports respectively while counts of seriously injured occupants in remaining years were derived using the ratio of seriously injured occupants to killed occupants that were observed for Australia (see Table 2 of this report). These estimates of the observed number of occupants killed or seriously injured in Queensland are shown in the second column of Table 12.

The third column of Table 12 gives estimates of how many occupants would have been were seriously injured or killed in Queensland had the secondary safety of the Queensland passenger vehicle fleet not improved since 1991. It can be seen that an estimated 28 additional occupants would have been killed or seriously injured in 1992 if the secondary safety index remained at 1991 levels and that, in general, the disparity between observed annual estimates and estimates assuming the baseline secondary safety increased with each passing year. By 2006 it was estimated that nearly 1,300 additional occupants would have been seriously injured or killed had the secondary safety of the Queensland fleet not improved. Adding the difference in the annual estimates of occupants seriously killed or injured reveals that if the secondary safety of the Queensland fleet had not improved since 1991, there would be more than 7,000 additional cases of seriously injured or killed occupants over the period 1991-2006.

Table 12: Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), Queensland, 1991-2006

Year of crash	Killed or seriously injured occupants of motor vehicles		Difference	Cumulative
	Actual SSI	Baseline SSI (4.47%)		
1991	2,933	2,933	0	0
1992	2,961	2,989	28	28
1993	3,125	3,188	63	91
1994	3,488	3,600	112	203
1995	3,652	3,864	212	415
1996	3,470	3,726	256	671
1997	3,370	3,662	292	963
1998	2,493	2,743	250	1,213
1999	2,735	3,099	364	1,577
2000	2,923	3,380	457	2,034
2001	3,231	3,857	626	2,661
2002	3,063	3,731	668	3,329
2003	3,005	3,746	741	4,070
2004	3,411	4,397	987	5,057
2005	3,099	4,078	979	6,036
2006	3,604	4,863	1,258	7,294

Like Table 12, Table 13 also shows estimates of how improvements to the secondary safety of the Queensland fleet since 1991 have affected the level of road trauma observed in Queensland in the period 1991-2006. However in the case of Table 13, the measure of road trauma is reported in terms of fatally injured occupants of passenger vehicles. It can be seen from the third column of Table 13 that had the secondary safety of the Queensland fleet not improved from 1991 to 1992, an additional three fatalities could be expected. However, if the secondary safety of the fleet had still not improved by 2006, it was expected that 78 additional fatalities would have been observed in 2006. Over the period 1991-2006, more than 500 additional occupants would have died had the secondary safety of the Queensland fleet not improved since 1991.

Table 13: Estimation of the number of occupants of motor vehicles who would have been killed if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), Queensland, 1991-2006

Year of crash	Killed occupants of motor vehicles Actual SSI	 Baseline SSI (4.47%)	Difference	Cumulative
1991	268	268	0	0
1992	280	283	3	3
1993	289	295	6	8
1994	284	293	9	18
1995	300	317	17	35
1996	279	300	21	56
1997	246	267	21	77
1998	196	216	20	97
1999	215	244	29	125
2000	239	276	37	163
2001	228	272	44	207
2002	227	277	50	256
2003	211	263	52	308
2004	219	282	63	372
2005	222	292	70	442
2006	222	300	78	519

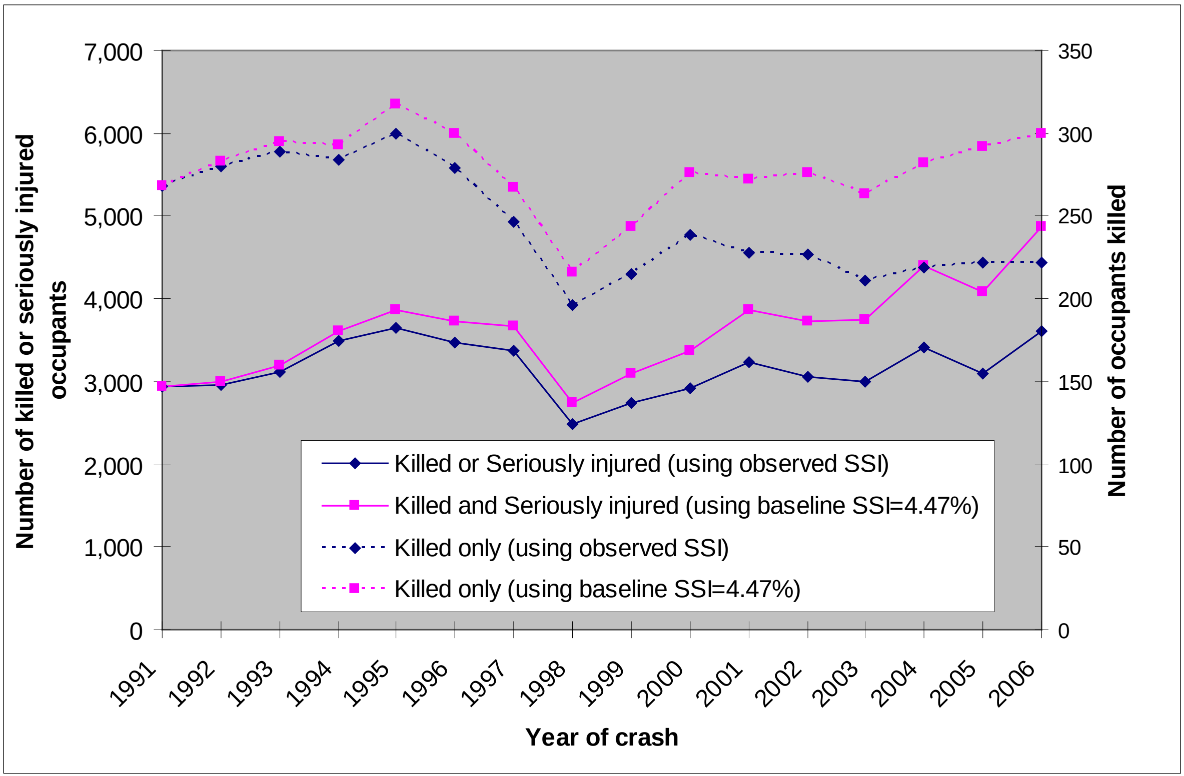

Figure 13: Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), Queensland, 1991-2006

Figure 13 illustrates the effect of improvements to the secondary safety of the Queensland passenger vehicle fleet on the number of occupants seriously injured or killed. As was the case for Figure 12 for New South Wales, solid lines represent estimates of the number of occupants killed or seriously injured, while dotted lines represent estimates of occupants who were killed and the right vertical axis corresponds to estimates relating to fatalities only, while the left axis corresponds to estimates for fatalities and seriously injured occupants. Pink markers represent estimates of the actual number of casualties while blue markers represent the number estimated if secondary safety improvements had not occurred.

3.3.3. South Australia

The second column of Table 14 shows estimates of the observed number of occupants of passenger vehicles killed or seriously injured for South Australia. As was the case for Queensland and New South Wales, the annual numbers of occupants killed in South Australia were estimated from the Australian Transport Safety Bureau's (2008) statistical summary of road deaths, while estimates of the number of occupants seriously injured were derived from the Federal Office of Road Safety's (1998) summary of road injury (for years 1991-1997) and Berry & Harrison's (2007; 2008) reports on serious injury for (2003 and 2006). Serious injury counts for remaining years were estimated using the ratio of serious injuries to fatalities observed for Australia.

Table 14: Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), South Australia, 1991-2006

Year of crash	Killed or seriously injured occupants of motor vehicles		Difference	Cumulative
	Actual SSI	Baseline SSI (4.47%)		
1991	1,588	1,588	0	0
1992	1,244	1,256	12	12
1993	1,269	1,295	26	37
1994	1,188	1,226	38	75
1995	1,200	1,270	70	145
1996	1,434	1,540	106	251
1997	1,507	1,637	130	381
1998	1,475	1,624	148	530
1999	1,386	1,571	185	714
2000	1,566	1,810	245	959
2001	1,516	1,810	294	1,253
2002	1,498	1,825	327	1,580
2003	1,605	2,001	396	1,976
2004	1,589	2,048	460	2,435
2005	1,493	1,965	472	2,907
2006	1,283	1,730	448	3,355

As police-reported crash data from South Australia were only available from 1995 onwards, a serious safety index based only on data from South Australia could not be estimated for every year in the period 1991-2006. However, Figure 7 in Section 3.2 suggests that the serious safety index for the South Australian fleet closely follows the trend of the serious safety index for Australia (Figure 6), which was derived using data from each state. This is convenient, for it allows the serious safety index derived using data from the five Australian jurisdictions to be used to as an accurate approximation of the secondary safety index of the South Australian fleet for the entire period 1991-2006.

It can be seen from the second column of Table 14 that if the secondary safety of the South Australian passenger vehicle fleet was assumed to remain unchanged since 1991 (i.e. equal to the secondary safety that was observed for the Australian fleet in 1991), twelve additional seriously injured or killed occupants would have been expected in 1992. If the secondary safety of the fleet still hadn't improved by 2005, it would be expected that an additional 472 occupants would have been seriously injured or killed on top of the 1,493 occupants that Berry & Harrison (2008) and the Australian Transport Safety Bureau (2008) estimated actually were seriously injured or killed.

Interestingly, unlike New South Wales and Queensland, where the disparity between the actual serious injury and fatality counts and the counts estimated under the baseline scenario generally increased with each passing year, for South Australia, the rate at which the difference between the two estimates increased slowed in later years. By 2006, the number of serious injuries prevented and lives saved due to improvements in the secondary safety of the South Australian fleet was less than the savings estimated in 2005. This trend was observed in Figure 10 of Section 3.3 which showed that, unlike other jurisdictions, the estimated annual savings for South Australia levelled off after 2003. The reason for the decline in the annual savings is that from 2003 onwards, the estimated number of occupants seriously injured or killed in South Australia has been falling (see the second column of Table 14), which was generally not the case for other Australian jurisdictions or Australia as a whole, where the estimated trends for the number of seriously injured or killed occupants were fairly steady (see Table 7 of Section 3.2 for the trend for Australia). It is possible that the reduction in estimates of the annual number of occupants seriously injured or killed in South Australia since 2003 could be due to the South Australian population increasing at a slower rate than that observed for the remaining five jurisdictions.

The fifth column of Table 14 shows that it was estimated that had the secondary safety of the South Australian fleet not improved since 1991, almost 3,400 additional occupants would have been killed or seriously injured over the period 1991-2006.

Table 15 also compares the level of road trauma that could be expected if the secondary safety of the South Australian fleet had not improved since 1991, however in this case the number of occupants killed was used to measure the level of road trauma. It can be seen that if the secondary safety of the fleet did not improved in 1992, only one more fatality would be expected. However, by 2006, it was estimated that 28 additional fatalities would have occurred in that year if the secondary safety of the 2006 fleet had not improved since 1991. It was estimated that over the entire period 1991-2006 nearly 250 fatalities have been prevented due to improvements in the secondary safety of the South Australian fleet.

Table 15: Estimation of the number of occupants of motor vehicles who would have been killed if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), South Australia, 1991-2006

Year of crash	Killed occupants of motor vehicles		Difference	Cumulative
	Actual SSI	Baseline SSI (4.47%)		
1991	126	126	0	0
1992	118	119	1	1
1993	149	152	3	4
1994	103	106	3	7
1995	120	127	7	14
1996	132	142	10	24
1997	110	120	10	34
1998	116	128	12	45
1999	109	124	15	60
2000	128	148	20	80
2001	107	128	21	101
2002	111	135	24	125
2003	123	153	30	155
2004	102	132	30	185
2005	112	147	35	220
2006	79	107	28	248

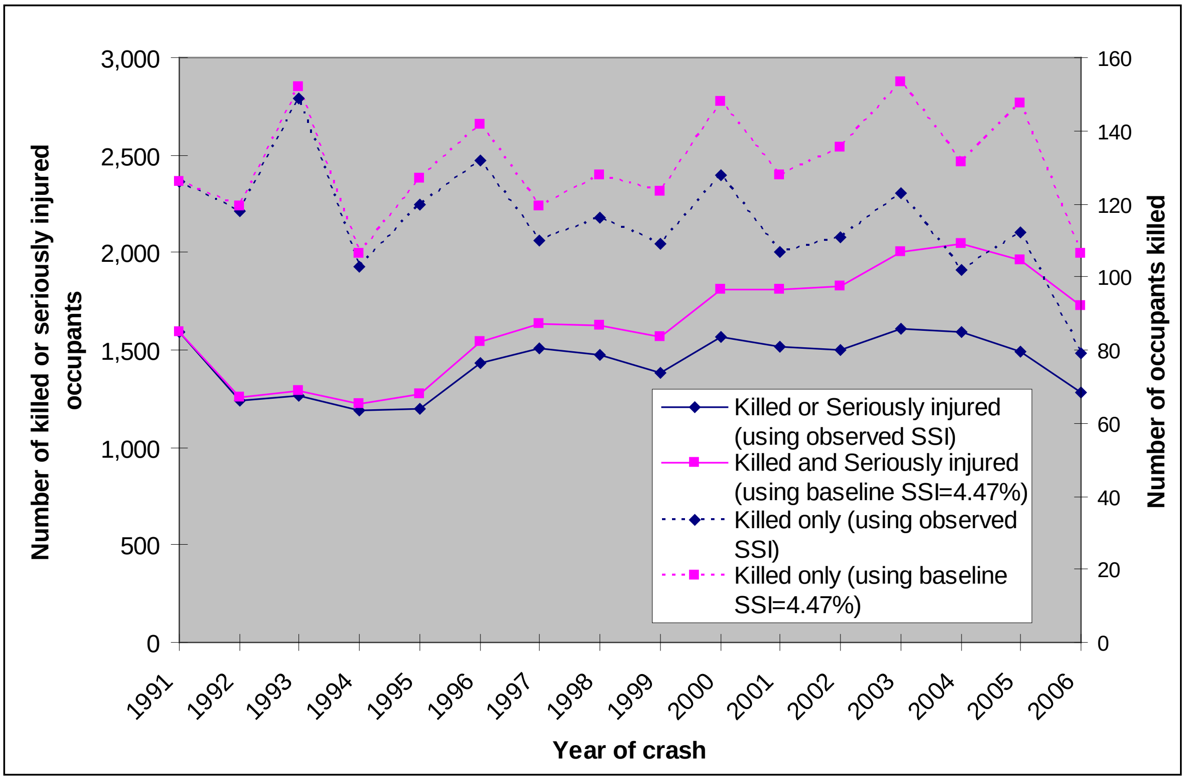

Figure 14: Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), South Australia, 1991-2006

Figure 14 graphically illustrates the serious injury and fatality trends for South Australia that would be expected under the baseline scenario compared to those estimated or observed assuming the secondary safety of the fleet did improve as observed.

3.3.4. Victoria

The second column of Table 16 shows the observed number of occupants who were killed or seriously injured in Victoria in the period 1991-2006. Like the other four Australian jurisdictions for which police-reported crash data were available, the number of occupants killed in Victoria were taken from the Australian Transport Safety Bureau's (2008) summary of road deaths, while estimates of the number of occupants seriously injured in the period 1991-1997 were taken from the Federal Office of Road Safety's (1998) summary of road injury and Berry & Harrison's (2007; 2008) reports on land transport injury were used to provide estimates of serious injury in Victoria for 2003 and 2005. However, unlike the other Australian jurisdictions, estimates for the number of occupants seriously injured in the period 1998-2002 and for the years 2004 and 2006 were derived using Victorian police-reported crash data. It was noted that for years in which data were available, the ratio of seriously injured occupants to killed occupants for Victoria was greater than that for other Australian jurisdictions. For example, in the period 1992-1996, the ratio for Victoria ranged from 13.2 to 16.7 serious injuries to fatalities, compared with 10.6 to 11.8 when data from all five jurisdictions were aggregated. As previously mentioned, the reason the serious injury to fatality ratio was higher for Victoria than other jurisdictions was that in Victoria, a road user was classified as being serious injured if they were transported to hospital by ambulance, while in other jurisdictions (excluding New South Wales), a road user must have actually been admitted to a ward for them to be classified as seriously injured.
Seeing the ratio of seriously injured occupants to killed occupants was higher for Victoria than for other jurisdictions, a different method to that used for other Australian jurisdictions was used to estimate Victorian serious injury counts for years in which these data were not available. Instead of multiplying observed fatality counts by serious injury to fatality ratios taken from data relevant to Australia as a whole, the Victorian police-reported crash data were used to estimate serious injury counts in the period 1998-2002 and the years 2004 and 2006.

Once annual counts of the number of occupants of passenger vehicles who were either seriously injured or killed were estimated, it was possible to estimate the annual counts of seriously injured or killed road users assuming that the secondary safety index remained at baseline levels for the entire period 1991-2006. These estimates are shown in the third column of Table 16. The fourth column shows the difference in the annual number of seriously injured or killed occupants and the number estimated if the secondary safety of the Victorian fleet remained at 1991 levels. It can be seen that after one year of the secondary safety index remaining fixed, it was estimated that there would have been an additional 40 cases of seriously injured or killed road users, while if the secondary safety of the fleet had not improved by 2006, it was expected that there would be approximately 1,800 additional occupants seriously injured or killed. The fifth column of Table 16 shows that over the entire period 1991-2006, improvements to the secondary safety of the fleet since 1991 have resulted in an the number of seriously injured or killed occupants being more than 11,000 less than would other wise have been expected.

Table 16: Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), Victoria, 1991-2006

Year of crash	Killed or seriously injured occupants of motor vehicles		Difference	Cumulative
	Actual SSI	Baseline SSI (4.47%)		
1991	4,493	4,493	0	0
1992	4,218	4,258	40	40
1993	4,318	4,405	87	127
1994	4,394	4,534	140	267
1995	4,633	4,902	269	537
1996	4,509	4,842	333	870
1997	4,221	4,586	365	1,235
1998	4,722	5,196	474	1,710
1999	4,557	5,164	607	2,316
2000	4,856	5,615	759	3,075
2001	5,136	6,132	996	4,071
2002	5,100	6,213	1,113	5,184
2003	4,963	6,187	1,224	6,408
2004	4,833	6,231	1,398	7,806
2005	5,029	6,618	1,589	9,395
2006	5,173	6,979	1,806	11,201

Table 17: Estimation of the number of occupants of motor vehicles who would have been killed if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), Victoria, 1991-2006

Year of crash	Killed occupants of motor vehicles		Difference	Cumulative
	Actual SSI	Baseline SSI (4.47%)		
1991	340	340	0	0
1992	238	240	2	2
1993	305	311	6	8
1994	258	266	8	17
1995	282	298	16	33
1996	289	310	21	54
1997	250	272	22	76
1998	250	275	25	101
1999	259	293	34	136
2000	288	333	45	181
2001	293	350	57	237
2002	276	336	60	298
2003	245	305	60	358
2004	248	320	72	430
2005	242	318	76	506
2006	218	294	76	582

Table 17 also shows how improvements to the secondary safety of the Victorian fleet since 1991 have affected the level of road trauma in Victoria. However, while Table 16 measured road trauma in terms of the number of occupants seriously injured or killed, Table 17 measures road trauma in terms of the number of fatalities. It can be seen that over the period 1991-2006, the improved secondary safety of the Victorian fleet meant that nearly 600 lives have been saved. If the average secondary safety of the 2006 fleet was the same as that of the fleet in 1991, it was estimated that the road toll for 2006 would be 76 deaths greater than the observed figure of 218 occupant deaths.

Figure 15 graphically illustrates the effect of improvements in the secondary safety of the Victorian fleet in the period 1991-2006 on the number of seriously injured or killed occupants of passenger vehicles. It is interesting to note that for Victoria, in the period 2004-2006, the number of fatalities is increasing, while the estimated number of occupants seriously injured or killed is decreasing. It can also be seen that, for both fatalities alone and for the aggregate of fatalities and serious injuries, the disparity between annual estimates derived assuming the baseline secondary safety index and when the observed secondary safety index was assumed increases with each passing year.

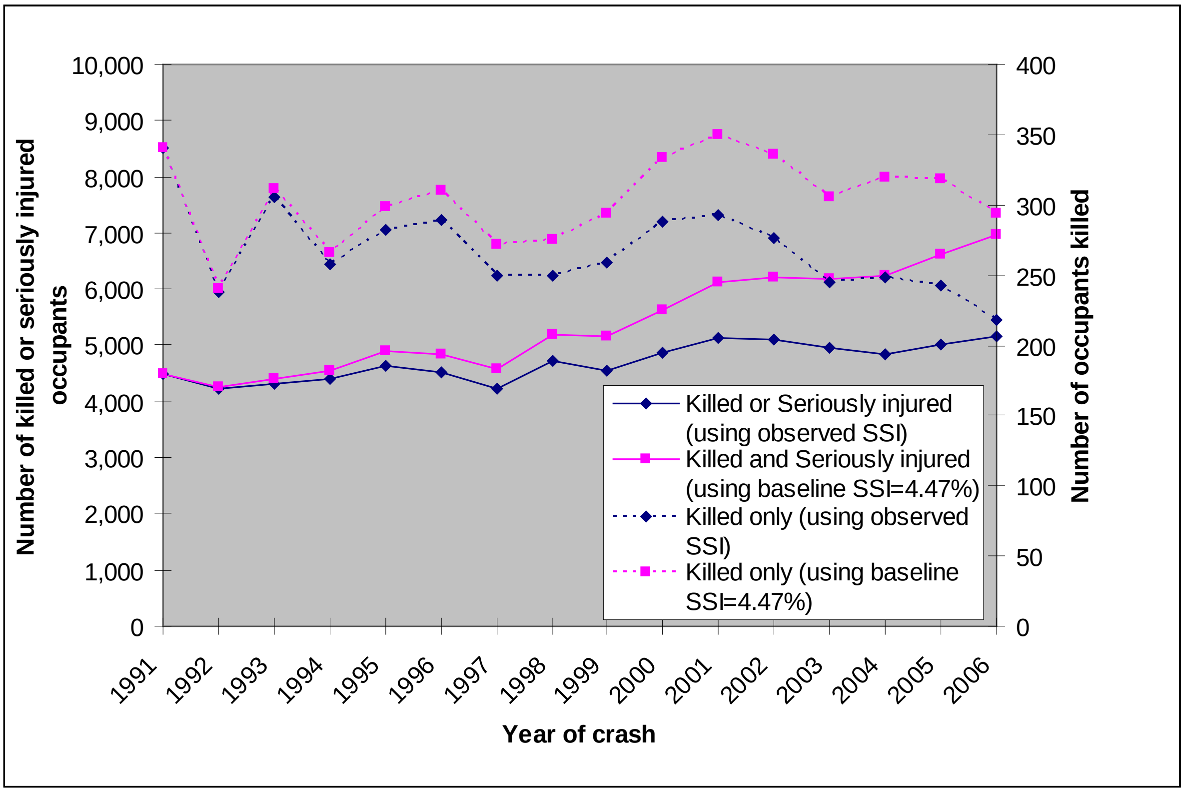

Figure 15: Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), Victoria, 1991-2006

3.3.5. Western Australia

Table 18 compares how the annual number of seriously injured or killed occupants of passenger vehicles in Western Australia would have changed if the secondary safety of the fleet had not improved since 1991. Annual estimates of the number of seriously injured or killed road users are shown in the second column of Table 18 and these estimates were derived in the same manner and using the same sources used to derive estimates for New South Wales, Queensland and South Australia. Specifically, the Australian Transport Safety Bureau's (2008) statistical summary of road deaths was the source for fatality counts while the Federal Office of Road Safety's (1998) report on road injury in Australia provided estimates of serious injury for the period 1991-1997 and Berry & Harrison's (2007; 2008) reports provided estimates for 2003 and 2005. Annual estimates of seriously injured occupants for all remaining years were derived by multiplying the observed number of occupants killed in Western Australia by the ratio of serious injuries to fatalities for the particular year, calculated using counts from all Australian jurisdictions.

Table 18: Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), Western Australia, 1991-2006

Year of crash	Killed or seriously injured occupants of motor vehicles		Difference	Cumulative
	Actual SSI	Baseline SSI (4.47%)		
1991	1,865	1,865	0	0
1992	1,967	1,986	19	19
1993	1,928	1,967	39	57
1994	2,186	2,256	70	127
1995	2,337	2,473	136	263
1996	2,084	2,238	154	417
1997	1,808	1,965	156	574
1998	1,997	2,197	201	774
1999	2,213	2,508	295	1,069
2000	1,859	2,150	291	1,360
2001	1,587	1,895	308	1,667
2002	1,687	2,055	368	2,035
2003	1,441	1,796	355	2,391
2004	1,978	2,550	572	2,963
2005	1,405	1,849	444	3,407
2006	2,370	3,198	828	4,234

This method of estimating the number of seriously injured road users in Western Australia for years in which such estimates were not reported by the jurisdiction probably resulted in the number of seriously injured occupants being underestimated for the years 2003 and 2005 when compared with other years. From the second column of Table 18 it can be seen that the estimated number of seriously injured or killed occupants was 1,441 in 2003 and 1,405 in 2005, while it was estimated that the number of occupants killed or seriously injured was 1,978 in 2004 and 2,370 in 2006. Counts for 2003 and 2005 were estimated using Berry & Harrison's (2007; 2008) estimates of the number of serious injuries and the Australian Transport Safety Bureau's (2008) reported number of fatalities. Estimates for 2004 and 2006 were derived by multiplying the observed number of fatalities (from the Australian Transport Safety Bureau, 2008) by the ratio of serious injuries to fatalities for Australia, which was estimated to be 14.6:1 in 2004 and 15.2:1 in 2006. These estimates are higher than analogous ratios for 2003 and 2005 derived using Berry & Harrison's (2007; 2008) serious injury estimates, which were 9.4 and 10.6 respectively.

It is unclear whether the estimates of the number of occupants seriously injured derived using Berry & Harrison's (2007; 2008) estimates are underestimates of the actual number of seriously injured road users or whether estimates for other years over-represent the actual number of road users. It is beyond the scope of the present report to review deficiencies in the way injury severity is coded in each jurisdiction. However, Chapman & Rosman (2008) provide a detailed discussion of some of the problems with how injury severity is classified in Western Australia. They also provide an alternative coding strategy that may accurately capture the number of road users who experience serious injury outcomes when involved in crashes. The large changes from year to year in annual serious injury counts for Western Australia since 2000 are probably partly due to changes in the way injury data have been coded. This problem is not restricted to Western Australia and demonstrates that a "robust measure of serious injury is required by road safety strategists and policy analysts in order to understand the impact of interventions" (Chapman & Rosman, 2008, p.9). Until the mechanisms necessary for defining such a robust measure have been put in place, imperfect methods, such as the one used to derive the data in the second column of Table 18, must be used to estimate the number of serious injuries. This will result in annual crash counts that reflect the deficiencies in the coding of data as well as fluctuations in the actual performance of the road safety activities.

Table 19: Estimation of the number of occupants of motor vehicles who would have been killed if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), Western Australia, 1991-2006

Year of crash	Killed occupants of motor vehicles		Difference	Cumulative
	Actual SSI	Baseline SSI (4.47%)		
1991	141	141	0	0
1992	166	168	2	2
1993	140	143	3	4
1994	148	153	5	9
1995	159	168	9	18
1996	156	168	12	30
1997	132	143	11	41
1998	157	173	16	57
1999	174	197	23	80
2000	152	176	24	104
2001	112	134	22	126
2002	125	152	27	153
2003	138	172	34	187
2004	127	164	37	224
2005	121	159	38	262
2006	146	197	51	313

While there remain uncertainties regarding the accuracy of estimates of the number of occupants seriously injured, occupant fatalities are accurately recorded. The second column of Table 19 shows the number of occupants of passenger vehicles who were killed in

Western Australia for each year in the period 1991-2006. The third column shows the annual number of fatalities estimated if the secondary safety of the Western Australian fleet had not improved since 1991. It can be seen that if the secondary safety of the Western Australian fleet had not improved from 1991 to 1992, two more fatalities would have been expected in 1992. If the secondary safety of the fleet had not improved for the entire period 1991-2006, an additional 51 fatalities would have been expected in 2005, while 313 additional fatalities would have been expected over the entire period 1991-2006. Figure 16 graphically illustrates how changes in the secondary safety of the fleet have affected annual counts of the number of occupants killed or seriously injured.

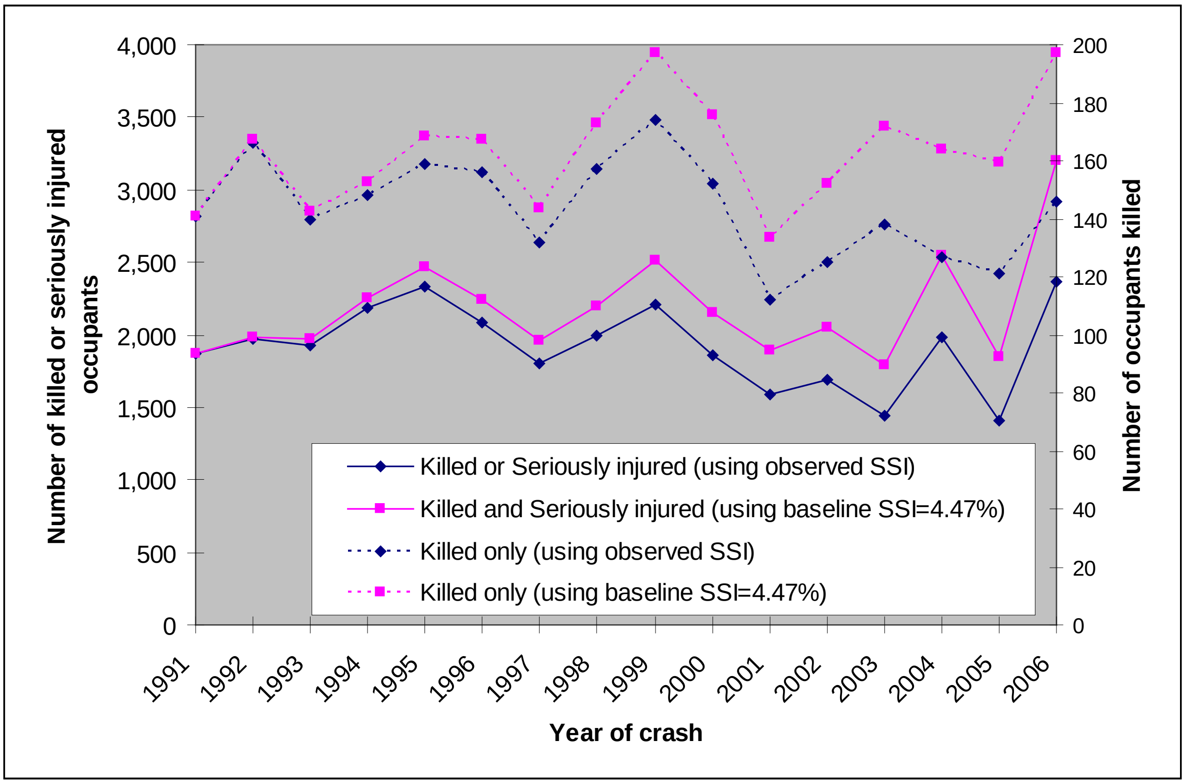

Figure 16: Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (4.47%), Western Australia, 1991-2006

3.4. Australia and New Zealand

In this section, data from the five Australian jurisdictions and New Zealand have been used to create a secondary safety index for Australasia. Figure 17 shows the secondary safety index for the Australian and New Zealand fleets combined compared to Australia only, the latter having been already derived in Section 3.2. It can be seen that the secondary safety index for Australia and New Zealand does not differ a great deal from that for Australia only.

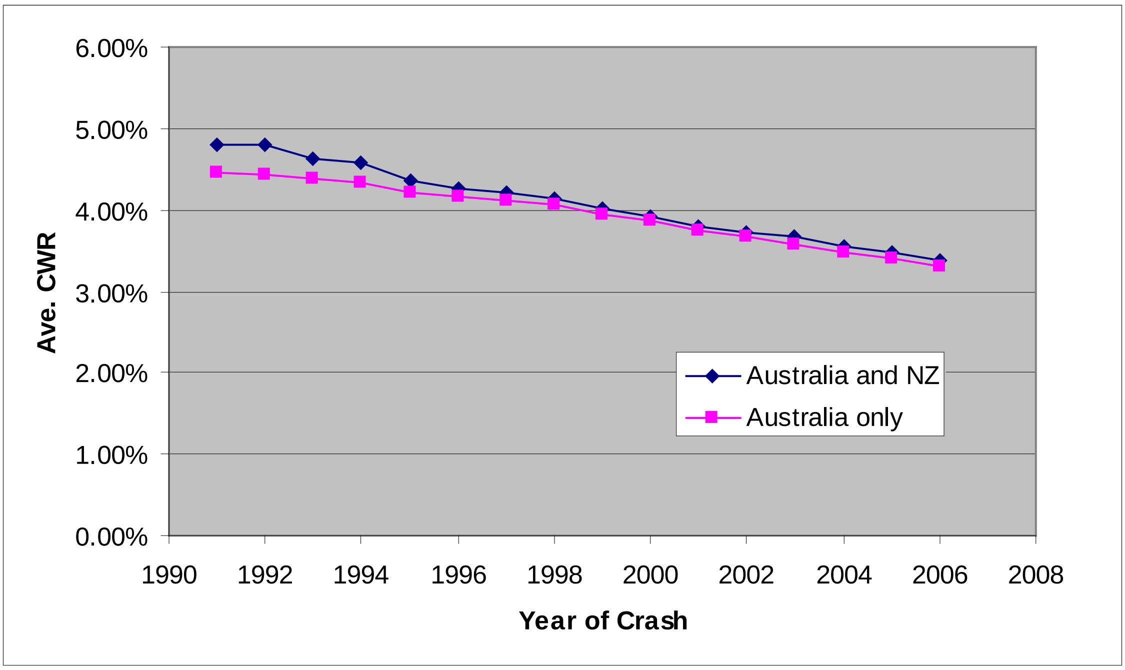

Figure 17: Secondary Safety Index (average fleet crashworthiness rating) for the Australasian (Australia and New Zealand) passenger vehicle fleet compared to the Australian passenger vehicle fleet (i.e. excluding NZ), 1991-2006

Table 20: Estimation of the number of occupants of motor vehicles who were involved in police-reported crashes using the observed SSI and the number of seriously injured or killed occupants, Australia and New Zealand, 1991-2006

Year of crash	Actual SSI	Occupants of Motor Vehicles Killed or Seriously injured	Occupants of Motor Vehicles Involved in police-reported crashes
1991	4.81%	20,143	418,731
1992	4.80%	19,005	395,824
1993	4.63%	19,015	410,441
1994	4.57%	19,714	431,484
1995	4.37%	20,045	458,576
1996	4.27%	19,520	457,097
1997	4.21%	18,972	450,179
1998	4.14%	17,462	421,706
1999	4.02%	18,158	451,882
2000	3.91%	18,127	463,849
2001	3.80%	19,036	500,730
2002	3.73%	18,631	499,241
2003	3.67%	20,272	552,992
2004	3.54%	19,862	560,300
2005	3.47%	20,579	593,040
2006	3.37%	20,039	594,523

The second column of Table 20 shows the secondary safety index for Australia and New Zealand while the third column shows the aggregated number of occupants seriously injured or killed for Australia and New Zealand. For each year, the estimated number of occupants seriously injured or killed was derived by simply summing the previously derived estimates from Tables 4 (for New Zealand) and 7 (Australia). Dividing the sum of these estimates for each year by the secondary safety index gives an estimate of the number of occupants involved in police-reported crashes in Australia and New Zealand. These estimates are presented in the right-most column of Table 20. Another way of deriving the estimates of the number of occupants involved in police-reported crashes in Australia and New Zealand would be to add the estimated number of occupants involved in police-reported crashes in Australia from Table 7 to the estimated number for New Zealand from Table 4. Using the latter method would result in the yearly estimates of the number of occupants being on average one percent less than those derived by dividing the number of occupants killed or seriously injured by the secondary safety index for Australia and New Zealand combined. Furthermore, the trend from year to year for the number of occupants involved in police-reported crashes is not affected by which method was used to derive the estimate, meaning that the choice of method is not critical.

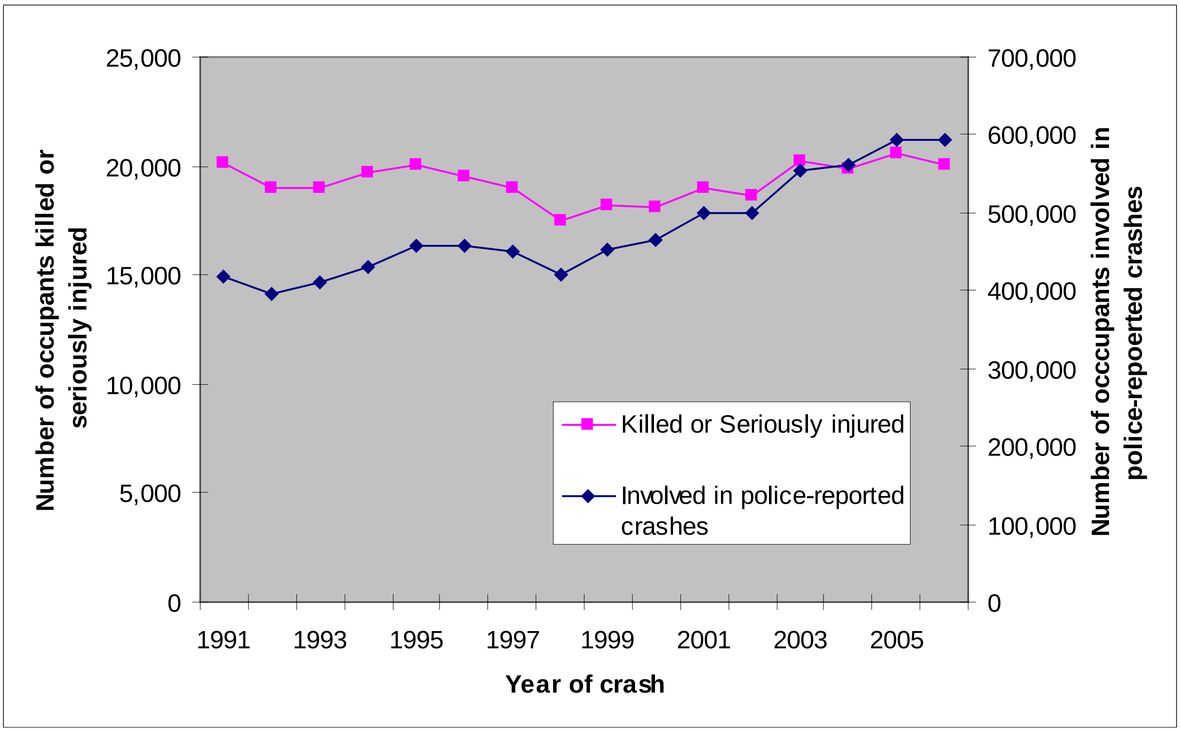

Figure 18: Estimation of the number of occupants of motor vehicles involved in police-reported crashes and the number seriously injured or killed in police-reported crashes, Australia and New Zealand, 1991-2006

Figure 18 shows a graphical representation of the estimated number of occupants involved in police-reported crashes in Australia and New Zealand compared to the observed number of occupants seriously injured or killed. It can be seen that, for Australia and New Zealand combined, the number of occupants involved in police-reported crashes has increased steadily over the period 1998-2006. In general, the annual number of occupants seriously injured or killed during that period has also risen, however not by the same proportion as the number of occupants involved. Specifically, in 2006, the number of occupants killed or seriously injured was 12.9% greater than the number of occupants killed or seriously injured in 1998, while the number of occupants involved in police-reported crashes in 2006 was 29.1% greater than that for 1998.

From Table 20 it can be seen that the secondary safety index for New Zealand and Australian fleets combined was estimated to be 4.8% in 1991. By 2006, the secondary safety index had improved to 3.4%. Presumably, this improvement in the safety of the combined fleet meant that there were less cases of occupants being seriously injured or killed than might otherwise have been expected. To quantify the extent to which secondary safety improvements have prevented cases of seriously injured or killed occupants, the average crashworthiness of the combined fleet was assumed to remain at 4.8% for each year in the period 1991-2006. The third column of Table 21 shows estimates of the number of occupants killed or seriously injured if the crashworthiness of the combined fleet was assumed to be 4.8% for each year in the period 1991-2006. The difference between these estimates and the observed number of seriously injured or killed occupants have been presented in the fourth column.

Table 21: Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (4.92%), Australia and New Zealand, 1991-2006

Year of crash	Killed or seriously injured occupants of motor vehicles		Difference	Cumulative
	Actual SSI	Baseline SSI (4.81%)		
1991	20,143	20,143	0	0
1992	19,005	19,041	35	35
1993	19,015	19,744	729	764
1994	19,714	20,756	1,042	1,807
1995	20,045	22,059	2,014	3,821
1996	19,520	21,988	2,468	6,289
1997	18,972	21,655	2,683	8,972
1998	17,462	20,286	2,824	11,796
1999	18,158	21,737	3,579	15,376
2000	18,127	22,313	4,186	19,562
2001	19,036	24,087	5,051	24,613
2002	18,631	24,016	5,385	29,998
2003	20,272	26,601	6,329	36,327
2004	19,862	26,953	7,091	43,418
2005	20,579	28,528	7,948	51,366
2006	20,039	28,599	8,560	59,926

The right-most column of Table 21 shows that it was estimated that there have been almost 60,000 fewer cases of death or serious injury in both countries in the period 1991-2006 due to the improved secondary safety of the Australian and New Zealand passenger vehicle fleets since 1991.

Table 22 also shows the impact of improvements in secondary safety since 1991 on the level of road trauma in Australia and New Zealand. However, instead of measuring road trauma in terms of serious injuries and fatalities, Table 22 measures road trauma in terms of fatalities alone. It can be seen that if the secondary safety of the Australasian fleet of passenger vehicles remained at the baseline level of 4.81% for the entire period 1991-2006, it was estimated that there would have been three more fatalities in 1992 than the number actually observed. In the following year it was estimated that 69 additional fatalities would have occurred if the serious safety index remained at 1991 levels. For all remaining years in the period 1991-2006, assuming that the fleet's secondary safety remained at 1991 levels would have lead to higher annual fatality counts than those actually observed. In 2006 it was estimated that improvements to the secondary safety of the Australasian passenger vehicle fleet would have saved 594 lives, while it was estimated that nearly 5,000 lives were saved over the entire period 1991-2006 due to improvements in the secondary safety of both fleets.

Table 22: Estimation of the number of occupants of motor vehicles who would have been killed if the secondary safety of the fleet had not improved from the baseline 1991 level (4.92%), Australia and New Zealand, 1991-2006

Year of crash	Killed occupants of motor vehicles		Difference	Cumulative
	Actual SSI	Baseline SSI (4.81%)		
1991	1,925	1,925	0	0
1992	1,850	1,853	3	3
1993	1,798	1,867	69	72
1994	1,748	1,840	92	165
1995	1,782	1,961	179	344
1996	1,757	1,979	222	566
1997	1,624	1,854	230	796
1998	1,569	1,823	254	1,049
1999	1,644	1,968	324	1,374
2000	1,678	2,066	388	1,761
2001	1,541	1,950	409	2,170
2002	1,523	1,963	440	2,610
2003	1,535	2,014	479	3,089
2004	1,477	2,004	527	3,617
2005	1,448	2,007	559	4,176
2006	1,390	1,984	594	4,770

Figure 19 provides a graphical illustration of the effect of secondary safety improvements on the Australasian passenger vehicle fleet.

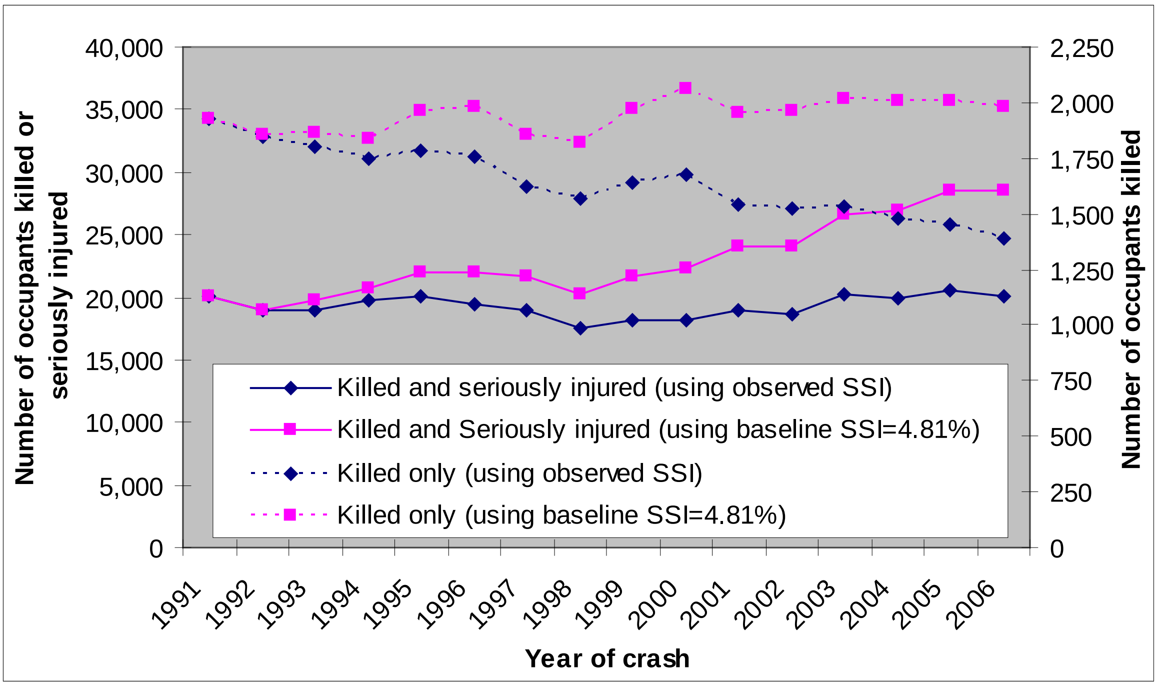

Figure 19: Estimation of the number of occupants of motor vehicles who would have been killed or seriously injured if the secondary safety of the fleet had not improved from the baseline 1991 level (4.81%), Australia and New Zealand, 1991-2006

4. DISCUSSION

4.1. Main findings

The aim of the present report was to develop an index of the average secondary safety of the passenger vehicle fleet in Australia and New Zealand and then quantify what effect improvements in secondary safety have had on the number of people seriously injured or killed due to road crashes. The index of secondary safety was defined by estimating the average crashworthiness for vehicles in each fleet for each year in the period 1991-2006. For Australia, it was found that the secondary safety index steadily improved with each passing year, with the risk of serious injury or death for occupants involved in police-reported crashes estimated to be 4.5% in 1991, but only 3.3% in 2006. For New Zealand, the serious safety index for 2006 was also better than that estimated for 1991 (4.2% in 2006 compared to 7.5% in 1991), however the New Zealand index did not decrease monotonically. The reason the average secondary safety of the New Zealand fleet sometimes increased from the estimate for the previous year is probably to do with New Zealand’s grey import program where used cars from overseas markets are imported into the New Zealand fleet.

Defining secondary safety indices for both countries enabled quantification of how many occupants of passenger vehicles would have been seriously injured or killed if the secondary safety of the fleets had not improved beyond 1991 levels.

One of the main findings of the report were that the Australian secondary safety index indicated that the secondary safety of the Australian fleet improved steadily over the period 1991-2006, from a 4.5% risk of death or serious injury given involvement in a police-reported crash in 1991 to a 3.3% risk in 2006. It was also found that the secondary safety index did not vary greatly when disaggregated across the five Australian jurisdictions which is an interesting result when considering that the different driving conditions of different Australian states may mean that the composition of the passenger vehicle fleet may differ from state to state.

As the observed secondary safety index for Australia improved with each passing year, the disparity between the observed number of occupants killed or seriously injured and the number estimated if there were no improvements to secondary safety also increased with each passing year. For example, in 1992 it was estimated that 153 more occupants would have been seriously injured or killed in Australia if the secondary safety of the fleet had not improved from 4.47% to 4.43%. If the secondary safety index had remained at 4.47% in 2006, an additional 6,196 cases of seriously injured or killed occupants would be expected in that year alone. It was estimated that over the period 1991-2006 there were approximately 39,000 fewer cases of occupants being seriously injured or killed than would have been expected if the secondary safety of the fleet had not improved since 1991.

Another finding was that improvements to the secondary safety of the New Zealand fleet since 1991 meant that nearly 13,000 fewer occupants were killed or seriously injured in the period 1991-2006 than would have been expected if the secondary safety index remained at 1991 levels during this time. This is equivalent to 31.3% fewer occupants being seriously injured or killed during this period than would have been expected if there were no change in the secondary safety of the fleet. By comparison, improvements to the secondary safety of the Australian fleet meant that the number of occupants killed or seriously injured in the period 1991-2006 was approximately 14.6% less than would otherwise have been expected. The difference between Australia and New Zealand in the savings due to the improved secondary safety expressed as a proportion of the observed number of serious injuries and deaths is due to differences in the magnitude of improvement in secondary safety exhibited for the two countries. Specifically, in the period 1991-2006 the secondary safety of the New Zealand fleet improved 44.5% (from 7.5% to 4.2%), while the secondary safety of the Australian fleet improved by 25.9% (from 4.5% to 3.3%).

4.2. Comparison with other Secondary Safety Indices

In completing this analysis, a number of interesting issues arose. Firstly it was noted that the secondary safety index for New Zealand that was estimated in the present report differed to that estimated by Keall & Newstead (2008). For example, when registration data were used by Keall & Newstead (2008) to define an index of secondary safety, the average crashworthiness of the fleet was consistently less than the analogous values estimated in the present report. However, when Keall & Newstead (2008) used crash data to estimate the index of secondary safety, the yearly estimates were very similar to those estimated in the present report. Keall & Newstead (2008) noted that a good secondary safety index could be defined for New Zealand using either crash data or registration data.

It should also be noted that the secondary safety indices presented in this report do not take into account the effect that non-vehicle factors may have on a vehicle's secondary safety. The secondary safety indices reported here were derived from estimates of crashworthiness that applied to a standardised set of crash circumstances and occupant characteristics (Newstead, Watson & Cameron, 2008a). Some vehicles may offer better protection to different types of occupants or different types of drivers. Therefore, the secondary safety index for the same group of vehicles may change over time as vehicles are transferred to different owners. However it should be noted that the crashworthiness ratings derived by Newstead, Watson & Cameron (2008a) were derived using data sourced over an extended period of time (1987-2006), meaning that the effect of transferring from one type of owner to another has been controlled for as best as possible.

4.3. The need for a consistent definition of *serious injury*

The report also highlighted that the definition of serious injury is not consistent across jurisdictions. Even if a serious injury is defined as an injury that requires admission to hospital, this may not guarantee a consistent definition of serious injury as different jurisdictions have different policies for what types of injuries require admission. Nor is the definition of serious injury consistent over time, with the threshold severity of injury after which admission to hospital is likely changes over time within a single jurisdiction. Temporal factors likely to affect the threshold severity level include the funding available to hospitals and the number of people presenting at emergency departments as well as changes in the way different types of injuries are treated.

It is unlikely that different jurisdictions will adopt a consistent definition of serious injury in the immediate future, nor is it likely that historical definitions of serious injury will match future definitions. For the purposes of comparing secondary safety across different jurisdictions and across different periods of time, secondary safety measures based on fatalities alone would be more reliable than measures based on serious injuries and fatalities. However, the relatively low numbers of fatalities that occur in New Zealand and Australia (compared to the number of serious injuries) mean that a metric based solely on fatality data will have very wide confidence limits which would prevent it from being useful for exercises such as the present analysis.

Chapman & Rosman (2008) provide a concise summary of the difficulties in deriving accurate estimates of serious injuries in Western Australia. Issues include the accuracy of police-reported data as well as using the hospital admission criteria when some relatively minor injuries often result in hospital admissions. It is likely that the issues raised by Chapman & Rosman (2008) are also relevant to other jurisdictions. As road safety strategists appear to favour using serious injury counts to measure the impact of road safety interventions, more work needs to be done to define a consistent and robust way of categorising the severity of injury.

4.4. Assumptions and qualifications and possible future work

In order to fulfil the aim of the report using the methodology described, a number of assumptions and qualifications had to be made. Firstly, it was assumed that the passenger vehicle fleet in Australia and New Zealand could be approximated using the sample of crashed vehicles from both countries. Keall & Newstead's (2008) comparison of secondary safety indices derived using crash data and registration data from New Zealand suggest that this assumption is valid. However, testing this assumption using registration data from an Australian jurisdiction would strengthen the validity of this particular assumption.

Another assumption was that the relative protection that a vehicle offers to all its occupants can be accurately approximated using the level of protection it offers to drivers. This assumption enabled Newstead, Watson & Cameron's (2008a) crashworthiness ratings, which measured the risk of serious injury for drivers only, to be used to define a metric that measured the ability of a passenger vehicle to protect all occupants.

In order to estimate the number of fatalities prevented due to improved secondary safety in the period 1991-2006, it was necessary to assume that the relative changes in the secondary safety index from year to year reflected relative changes in the risk of an occupant being killed when involved in a police-reported crash as well as changes in the risk of being seriously injured or killed. As mentioned in the results section, this assumption has not yet been tested. It would greatly strengthen the results of this report if this assumption was tested in the future. Alternatively, a metric of crashworthiness that specifically measured the risk of death could be developed and applied in the same way that the crashworthiness metric from Newstead, Watson & Cameron (2008a) was applied in this report. However it would be difficult to apply Newstead, Watson & Cameron's (2008a) methodology to define a secondary safety metric that measured the risk of death. This is because the death of a driver is a much rarer outcome than a driver being seriously injured. This will mean that the proportion of the fleet for which model-specific risk of death estimates can be derived would be much smaller than the proportion of the fleet for which Newstead, Watson & Cameron (2008a) were able to derive model-specific estimates of the risk of serious injury or death. A measure of the risk of death could possibly be derived if vehicles were grouped into broader categories defined by year of manufacture and market category but no differentiation was made between different models of vehicles. Such a metric would not be suitable as a tool to aid consumers in choosing safer used cars, but could prove useful for exercises such as the one attempted in the present report.

This analysis also assumed that the point-estimates of crashworthiness accurately represented the actual crashworthiness of vehicles in the dataset. In Newstead, Watson & Cameron's (2008a) update of the Vehicle Safety Ratings, each rating was presented as a point-estimate with 95% confidence limits. The value of the work presented in this report could be increased if the level of variability within each crashworthiness estimate was used to derive confidence limits for the secondary safety index defined in this report. This would in turn enable confidence limits to be placed around the estimated effects that improvements in secondary safety have had on the number of people seriously injured or killed due to road crashes. Section 3.2 revealed that in Australia there were about 39,000 fewer occupants killed or seriously injured in the period 1991-2006 due to improvements in the secondary safety of the fleet. Similarly, in section 3.1 it was estimated that there were about 12,600 fewer seriously injured or killed occupants in New Zealand. When these two estimates are aggregated, the estimated number of cases of seriously injured or killed occupants prevented in Australia and New Zealand due to improved secondary safety is approximately 52,000. This is less than the saving of approximately 60,000 cases of serious injury or death estimated when New Zealand and Australian crash data were combined to derive a single serious safety index for Australasia (see Section 3.4). The disparity between the two sets of estimates could be better understood if both sets of estimates could be presented with confidence limits.

Finally, as noted by Keall & Newstead (2008), when estimating the effect of improved safety on the number of seriously injured or killed occupants in New Zealand, it might be advantageous to use estimates of crashworthiness for vehicles grouped by market group and year of manufacture that were derived from New Zealand data only. In the present report, like Keall & Newstead (2008), New Zealand vehicles that could not be assigned a crashworthiness rating based on make and model values were given crashworthiness ratings based on their market group and year of manufacture. Only the estimates for vehicles grouped by year of manufacture were derived using New Zealand crash data, with estimates based on market group and year of manufacture or make and model codes being derived using both Australian and New Zealand crash data.

5. REFERENCES

Australian Bureau of Statistics (2005) *9309.0 Motor Vehicle Census, 31 March 2005*, Canberra.

Australian Bureau of Statistics (2008) *3101.0 Australian Demographic Statistics - Table 4: Estimated Resident Population, States and Territories (Number), June 2008*, Time Series Workbook, Canberra.

Australian Transport Council (2002) *The National Road Safety Strategy 2001-2010*, Prepared by the Australian Transport Safety Bureau, Canberra.

Australian Transport Safety Bureau (2008) *Road Deaths Australia: 2007 Statistical Summary*, Road Safety Report No. 1, Department of Infrastructure, Transport, Regional Development and Local Government, Canberra, Australia.

Berry, J.G. & Harrison, J.E. (2007) *Serious injury due to land transport accidents, Australia, 2003-2004*, Injury Research and Statistics Series Report No. 38, Catalogue No. INJCAT 107, Australian Institute of Health and Welfare, Canberra, Australia.

Berry, J.G. & Harrison, J.E. (2008) *Serious injury due to land transport accidents, Australia, 2005-2006*, Injury Research and Statistics Series Report No. 42, Catalogue No. INJCAT 113, Australian Institute of Health and Welfare, Canberra, Australia.

Bureau of Transport Economics (2000) Road crash costs in Austalia, Report 102, Bureau of Transport Economics, Canberra, Australia.

Burton, D., Delaney, A., Newstead, S., Logan, D. & Fildes, B. (2004) Evaluation of Anti-lock Braking Systems Effectiveness, RACV Report Number 04/01, Melbourne, Australia.

Cameron, M.H., Finch, C.F. & Le, T. (1994) *Vehicle Crashworthiness Ratings; Victoria & NSW Crashes During 1987-98 – Technical Report*, Report No. 58, Monash University Accident Research Centre, Melbourne, Australia.

Chapman, A. & Rosman, D.L. (2008) *Measuring road crash injury severity in Western Australia using ICISS*, Insurance Commission of Western Australia Road Safety Forum and Awards, 6 November, Perth.

Federal Office of Road Safety (1998) *Road injury Australia: Crashes Resulting in Hospitalisation*, 1996 Statistical Summary, Federal Office of Road Safety, Canberra, Australia.

Keall, M.D. & Newstead, S.V. (2008) *Development of a benchmark tool for the secondary safety of the New Zealand light vehicle fleet*, Report to New Zealand Ministry of Transport, Monash University Accident Research Centre, Melbourne, Australia.

Ministry of Transport (2003) *Road Safety to 2010*, Yearly Report 2008, Ministry of Transport, New Zealand.

Ministry of Transport (2008) *Motor vehicle crashes in New Zealand 2007: Statistical statement calendar year 2007*, Yearly Report 2008, Prepared by Transport Monitory, Strategy & Sustainability, Ministry of Transport, New Zealand.

Newstead, S., Delaney. A., Watson. L. & Cameron, M. (2004) *A model for considering the 'total safety' of the light passenger vehicle fleet*, Report No. 228. Monash University Accident Research Centre, Melbourne, Australia.

Newstead S., Watson L. & Cameron M. (2008a) *Vehicle safety ratings estimated from police reported crash data: 2008 update. Australian and New Zealand crashes during 1987-2006*, Report No. 280. Monash University Accident Research Centre, Melbourne, Australia.

Newstead, S., Watson, L. & Cameron, M. (2008b) *Trends in crashworthiness of the New Zealand vehicle fleet by year of manufacture: 1964 to 2006. Supplement to report 280 Vehicle safety ratings estimated from police reported crash data: 2008 update*, Report No. 280 supplement. Monash University Accident Research Centre, Melbourne, Australia.

Scully, J. & Newstead S. (2008) *Evaluation of electronic stability control effectiveness in Australasia*, Accident Analysis and Prevention, 40, 2050-2057.